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AND
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R. L. Faris

Terrestrial Magnetism *and* *Atmospheric Electricity*

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A NEW THEORY OF MAGNETIC STORMS

BY S. CHAPMAN AND V. C. A. FERRARO

PART I—THE INITIAL PHASE (Continued)*

9. *The variation of pressure, density, and temperature near the head of the stream*

BY V. C. A. FERRARO

9.1—The examination of the conditions in the gas near the head of the stream should, to be satisfactory, be based on a kinetic theory treatment. As yet we have not succeeded in developing such a treatment, and are, for the time being, forced to adopt less fundamental, and therefore less certain, methods. In particular we now assume that the value of R_e/l_e at the front boundary of the stream is at least of order unity, on the ground that if it becomes less than unity the electrons will be unable to continue their advance (with the ions) into the field.

If R_e/l_e is of order unity at the boundary, and exceeds unity in the stream, the electrical conductivity even in the shielding layer will be of the same order of magnitude as the full electronic $(\sigma_e)_0$ of §8.1. Hence the thickness of the shielding layer will be similar to that estimated in §8.2.

At Z earth-radii from the Earth's center, R_e/l_e** $=4\times10^{-11}NZ^3$ when $T=6000°$. Thus the assumed condition requires that, at the front of the stream N is at least of the order $2\times10^{10}/Z^3$ ions per cc, or $(2\times10^{10}/Z^3)\,(T/6000)^{3/2}$ if T differs from 6000°.

At distances $Z=5$ and 2, and for $T=6000°$, the corresponding order of N is 2×10^8 and 10^9; these values exceed what seems to be the probable value of N in the stream in the neighborhood of the Earth, apart from the disturbance of the stream by the Earth's magnetic field. According to §8 the density near the front of the stream can be raised to this value by the in-pouring matter from behind, as the front layer is retarded. The proportionate increase may be less than was there calculated, however, on account of the backward pressure-gradient accompanying the increase of density—particularly if the compression of the stream of gas raises the temperature as in the adiabatic compression of an ordinary

*Continued from this Journal, **36**, 77-97 and 171-186 (1931), **37**, 147-156.

**Here, as in §8, it must be remembered that R_e is not the spiral radius which the electrons would execute in the magnetic field with their velocity of 10^8 cm per sec.; it would be more accurate (but perhaps less simple) to replace R_e/l_e by ν_e/ω_e, where ω_e $(=eH/mc)$ is the frequency of spiralling of the electrons and ν_e $(=C_e/l_e)$ the frequency of collisions, where C_e is the mean thermal velocity of the electrons.

gas. The extent to which these factors should be considered depends on the frequency of collisions, and therefore on the density and temperature of the stream.

A calculation bearing on these points will now be given in brief. In the first place it will be supposed that the conditions are isothermal, and afterwards (§9.9) the modification due to variation of temperature will be considered. The analysis is an extension of that of §8, and is limited by the same approximations as were there adopted to lessen the mathematical difficulties. No account is taken of any flow of matter transverse to the stream.

9.2—Using the coordinates of §8.4, the equation of motion of an element at the point (0, 0, z) will be

$$\rho\ddot{z} = F - \frac{\partial p}{\partial z} \tag{99}$$

which differs from (57) by addition of the term $-\partial p/\partial z$. Assuming for the present that the conditions remain isothermal, the pressure will be given by

$$p = kNT = R\rho \tag{100}$$

where (approximately)

$$R = (2/3)\, C^2 \tag{101}$$

C being the mean thermal velocity of the positive ions. For $T = 6000°$, the values of R for hydrogen and calcium ions are respectively

$$R_H = 9{\cdot}6\times10^{11} \text{ and } R_{Ca} = 2{\cdot}4\times10^{10} \tag{102}$$

Substituting (65) in the equation of motion (99), and proceeding as in §8, we deduce an equation of the form

$$\rho_\infty\,(\psi_1 + \psi_2) = 0$$

where

$$\psi_1 = -\ddot{g}\,\left(Q - g\frac{\partial Q}{\partial d}\right) + Rg\frac{\partial^2 Q}{\partial d^2} + \frac{1}{2}\frac{\sigma w}{\rho_\infty}H_0^2 f^3 \tag{103}$$

whilst ψ_2 (whose form need not be considered here) vanishes identically at the boundary $z = z_0$, or $d = 0$; it is therefore small for sufficiently small values of d, and hence, as in §8, an approximate solution of equation (99), valid near the boundary, is a solution of the equation $\psi_1 = 0$.

If we set

$$\epsilon = \ddot{g}/R\,, \quad b = 6\pi\sigma w, \quad \beta = \frac{1}{2}\frac{\sigma w}{\rho_\infty}\frac{H_0^2}{Rg} = \frac{bH_0^2}{12\pi\, Rg\,\rho_\infty} \tag{104}$$

this equation can be written

$$\frac{\partial^2 Q}{\partial d^2} + \epsilon\frac{\partial Q}{\partial d} - (\epsilon/g)Q = -\beta f^3 \tag{105}$$

the solution of which can be obtained in terms of integrals analogous to (80). These cannot be evaluated in finite terms, and here it seems suffi-

cient to replace f^3 by the approximate form (valid near the boundary) e^{-bd}. The general solution of (105) is then

$$Q = Q_1\, e^{-q_1 d} + Q_2\, e^{q_2 d} - \beta e^{-bd}/(b^2 - \epsilon b - \epsilon/g) \tag{106}$$

where Q_1, Q_2 are arbitrary functions of the time t, and

$$q_1 = \frac{\epsilon}{2}\left\{\left(1+\frac{4}{\epsilon g}\right)^{1/2}+1\right\},\quad q_2 = \frac{\epsilon}{2}\left\{\left(1+\frac{4}{\epsilon g}\right)^{1/2}-1\right\} \tag{107}$$

One condition to be satisfied is that Q must tend to zero as $(z-z_0)\rightarrow -\infty$ (cf. §8.4, p. 152); we cannot apply this condition directly to (106) because (105) is only valid for small values of d. But since we could regard (106) as a solution of the equation (99) provided that F were increased by the amount $\rho_\infty\, \psi_2$, a solution of this equation which least deviates from the actual solution is that for which $Q_2 = 0$, because this makes ψ_2 smallest. Hence we choose the solution

$$Q = Q_1\, e^{-q_1 d} - \beta e^{-bd}/(b^2 - \epsilon b - \epsilon/g) \tag{108}$$

To complete the solution we require another condition at the boundary of the stream $d=0$; as we have said in §9.1, this can only be determined by a kinetic theory treatment, in the absence of which it becomes necessary to assume such a condition as seems likely to approximate to the truth.

The force acting on the ions is made up of the electromagnetic force F and the pressure gradient $-\partial p/\partial z$; near the front boundary of the stream it seems improbable that the latter can numerically exceed F. Thus the ratio

$$\theta = \left(-\frac{\partial p}{\partial z}/F\right)_{d=0}$$

seems likely to be a fraction numerically less than 1. Moreover, since the density is likely to decrease as we move inwards from the boundary, θ is unlikely to be negative. Its variation is thus likely to be slow as the stream advances into the field, and for this reason we shall treat it as constant. This is the assumption we make and it will be seen later (§9.5) that it is not inconsistent with the assumption that $(R_e/l_e)_{d=0}$ is not less than unity.

The above condition can be written in the form

$$\frac{\partial^2 Q}{\partial d^2} = \theta\beta \tag{109}$$

where $d=0$, and θ is a positive non-dimensional number of order unity. Applying this condition at $d=0$ to the equation (108), it can be shown that to lead to the equation of motion of the front of the stream, which is approximately given by

$$\ddot{g} = R\kappa g\beta/(1+g\sqrt{\kappa\beta}) \tag{110}$$

where

$$\kappa = 1+\theta \geqq 1 \tag{111}$$

At large distances from the Earth, where $g\,(\kappa\beta)^{1/2} << 1$, the equation of motion becomes approximately

$$(112) \qquad \ddot{z}_0 = -\kappa b H_0^2 / 12\pi\rho_\infty$$

This means that the density is approximately uniform throughout the stream during the early stages of the motion—and this is clearly true provided $\kappa = 1$. The equation (112) can also be obtained if we make $R \to \infty$ and hence $T \to \infty$, which suggests that if the temperature of the stream is infinitely large there can be no heaping up of matter.

9.3—If we write

$$(113) \qquad \gamma = (\kappa b / 12\pi\rho_\infty) H_a^2 / R$$

(110) becomes

$$(114) \qquad \ddot{g} = R\gamma / Z^3 \, (Z^3 - \sqrt{\gamma g})$$

The solution of this equation, which is similar in some respects to (32) in §7, can be discussed by the method given there; and it may be remarked here that both these equations have no solutions such that $v \to 0$ as $Z \to 0$. The (at first sight surprising) absence of such solutions means that the front of the stream would be brought to rest before reaching the origin—a result which is unlikely. The explanation is to be sought in the admittedly approximate methods used either in formulating the simplified problem (§7) or in the mathematical approximations used (§§8, 9). In §7 the equation (32) is no longer valid when the velocity of the stream is reduced to a small fraction of its initial value, since it takes no account of the thickening of the current layer, which increases like $1/w$ (cf. §8.2). In the problem considered in §8 and in the present case the result is probably due to the neglected term ψ_2. The solutions of these equations, nevertheless, give at least an indication of the orders of magnitude, since ψ_2 vanishes at the boundary and at an infinite distance, and does not exceed the value of the terms retained in the equation of motion at the boundary, except possibly when w is reduced considerably.

9.4—The equation (114) has been solved partly analytically and partly numerically down to the region in which w/w_∞ first begins to decrease rapidly; the solution which is of importance for our application has the approximate form

$$(115) \qquad g = \left(\frac{9}{10}\right)^{2/3} \left(\frac{\kappa b M^2}{12\pi\rho_\infty w_\infty{}^2}\right)^{1/3} \left(\frac{R}{w_\infty{}^2}\right)^{1/3} \frac{1}{(-z_0)^{2/3}}$$

M being the magnetic moment of the Earth. Inserting numerical values for the various constants, taking $w_\infty = 10^8$ cms per sec., $T = 6000°$, this becomes

$$(116) \qquad g = (\kappa / A^2 N_\infty)^{1/3} \, 2 \cdot 8 \times 10^{12} / (-Z)^{2/3}$$

and this solution is valid in the region

$$(117) \qquad 120 \, (\kappa / A^2 N_\infty)^{1/5} < -Z < 1000 \, (\kappa / A^2 N_\infty)^{1/5}$$

It is of interest to compare (116) with the corresponding value obtained in §§7 and 8; there we find

$$(118) \qquad g = \tfrac{1}{6} (M^2 / 2\pi\rho_\infty w_\infty{}^2)^{1/2} / (-z_0)^2 = 10^{11} / (A N_\infty)^{1/2} (-Z)^2$$

Hence the compression-interval g varies much more slowly with the distance $-Z$ when account is taken of the pressure-gradient, as here, and also it is very much larger; such a result was to be expected, because the matter near the head continually tends to spread itself backwards and thus to diminish the density and increase the retardation of the particles in the stream.

For reasons stated in §9.3 we cannot deduce from the solution of (114) the motion of the front of the stream during the final stage when the velocity of the stream is being reduced to zero; it seems not improbable that this further decrease in velocity will be rapid at first, and afterwards very slow, in a manner similar to that indicated by the curves in Figure 7, §7.8. But during this last stage the flow of matter *along* the lines of magnetic force may become of importance, and the rise in the magnetic field produced by the stream may begin to decrease as soon as the velocity of the front surface is reduced to, say, 1/10 of its original value. The average intensity of the initial phase of a magnetic storm is about 30γ, and, as was shown in §7.9, this would be produced if the front of the stream came within 5 Earth-radii from the Earth. From (117) it follows that A^2N_∞/κ must be of order 8×10^6; since κ is likely to be of order 1, this would mean that A^2N_∞ must be of order 8×10^6. For streams composed of hydrogen and calcium ions respectively, the requisite densities of emissions at the Sun would have to be about 4×10^{11} and 2×10^8 respectively, taking account of the geometrical broadening of the stream. The value for hydrogen, although an overestimate, seems much too high for the density of the stream at the Sun's surface; the corresponding value for calcium appears more satisfactory, though it also seems high. But these estimates are tentative, and might be reduced by a factor of 10, or even 100, if a more accurate examination of the state of the gas near the front of the stream could be made. The values of N_∞, however, seem unlikely to be smaller than 10^7 and 10^5 for H and Ca, because these estimates cannot be smaller than those deduced from the analysis given in §8.

It seems worth while pointing out that the required densities of emission from the Sun as here estimated differ by a factor as large as 10^3, apparently because both the thermal molecular velocity and the retardation of the particles in a calcium-stream are considerably smaller than those for a hydrogen-stream.

9.5—We next examine the distribution of matter within the stream. To a first approximation we find

$$(119)\qquad Q=e^{-q_1 d}$$

where q_1 is nearly equal to $\ddot{g}/R$, or $-(\gamma/g)^{1/2}Z^3$; on inserting numerical values for γ and g from (113) and (116), we find

$$(120)\qquad q_1=0.079\,(\kappa A/N_\infty)^{1/3}/(-Z)^{8/3}$$

The excess density is, by (75), proportional to $\partial Q/\partial d$ and hence to $e^{-q_1 d}$, and the gradient of density thus depends on q_1. This function increases with $-Z$ at a somewhat rapid rate and, as was to be expected, is larger the larger the value of A, that is, the heavier the atom. On the other hand, it varies like $N_\infty^{-1/3}$, so that the concentration of matter is least when the initial density is highest—a result which is otherwise evi-

dent since the retardation of the stream is smaller the larger N_∞ is. Since κ is also of order unity, (120) is approximately equal to 0.079 $(A/N_\infty)^{1/3}/(-Z)^{8/3}$. Thus, 99 per cent of the excess mass accumulated at the front will be contained in a layer 58 $(N_\infty/A)^{1/3}$ $(-Z)^{8/3}$ cm thick. At a distance $-Z=5$ and for $N_\infty=8\times10^6/A^2$, this becomes 9.4/A km, or 9.4 km and 0.23 km in the case of hydrogen- and calcium-streams, respectively. It is not surprising that these estimates considerably exceed that—of about 4 cm—given in §8. The latter, however, remains the estimated thickness of the electric current-layer, calculated from the kinetic-theory value of the conductivity; not much significance can be attached to it, in view of the much larger value of the mean free-path even at the head of the stream.

The excess density at the front of the stream is equal to $-N_\infty g\ (\partial Q/\partial d)_{d=0}$, by (75), or gq_1N_∞. Using (116) and (120) we deduce

(121) $N=(N_\infty/A)^{1/3}\ 2\times10^{11}/(-Z)^{10/3}$ ions per cc or, taking $N_\infty=8\times10^6/A^2$,

(122) $$N=4\cdot4\times10^{13}/A(-Z)^{10/3}$$

In §9.1 we have seen that for R_e/l_e to be at least of order unity, it was necessary for the density to be of the order of $2\times10^{10}/(-Z)^3$ at least; comparing this with (122) it is seen that the condition would be satisfied both for H- and Ca-streams at the head of the stream. It is also satisfied within the stream, because the density increases much more slowly than the magnetic field as we move inwards from the surface, and the difficulty with regard to this mentioned in §8.42 does not arise.

We wish to emphasize the uncertainty which is attached to this investigation, because of the assumptions and approximations involved; but the results do not seem to us improbable.

9.6—According to (122) the density of the gas near the front of the stream would be increased in the ratio $2.0\times10^{10}/(AN_\infty^2)^{1/3}\ (-Z)^{10/3}$; this, as was to be expected, is larger the rarer the stream and the lighter the ions present, and except for very large values of N_∞ (for example, 10^{15} ions per cc), and at large distances from the Earth, this ratio will be large in comparison with unity. Taking, for example, as before $N_\infty=8\times10^6/A^2$, the values of this ratio at distances from the Earth equal to $-Z=5$, 3, 2 would be $2\cdot6\times10^4 A$, $1\cdot4\times10^5 A$, $5\cdot5\times10^5 A$, respectively. For Ca-ions this is as large as 10^7.

Such a large increase of density would be accompanied by a rise in temperature if, by collisions, part of the kinetic energy of the stream is converted into random motion. It is of importance to examine this point in some detail since it considerably affects the estimates of the increase in density.

We find that, of the total kinetic energy transformed during the advance of the stream into the Earth's magnetic field, only a small fraction reappears as magnetic energy due to the magnetic effects produced by the current-bearing layer: Thus at a distance of 5 Earth-radii from the Earth, taking as usual $N_\infty=8\times10^6/A^2$, $w=(1/2)w_\infty$, this fraction is about 0.001 and 0.04 for the cases of streams composed respectively of hydrogen and calcium atoms. This suggests, therefore, that a large proportion of the kinetic energy of the stream becomes transformed into heat-energy.

The preceding analysis suggests that in the layer containing 99 per cent of the excess mass accumulated, the variations in velocity from point to point are small compared with the velocity of the front of the stream (unless this is very small indeed, for example, about 10^3 or 10^4 cm per second). The whole layer may therefore be supposed to move bodily with a velocity equal to that of the front of the stream. If this velocity is reduced to a fraction f of its initial value w_∞ $(=10^8)$, a proportion $1-f^2$ of the kinetic energy is converted mainly into heat-energy. If this is not dissipated from the stream, the temperature must rise considerably. Thus, if C refers, as before, to the thermal velocity of the positive ions at the temperature of 6000°, the temperature will be raised approximately in the ratio $\{(1-f)\,w_\infty+C\}^2/C^2$. Hence, when the velocity of the front of the stream is reduced by 10^6, 10^7, 10^8 cm per second, corresponding to $(1-f)$ being 1/100, 1/10, 1, the temperature would rise to $2{\cdot}4\times10^4$, $4{\cdot}2\times10^5$, $4{\cdot}2\times10^{7}$°k in the case of hydrogen, and to $1{\cdot}7\times10^5$, $1{\cdot}7\times10^7$, $1{\cdot}7\times10^{9}$°k in the case of calcium-streams. These temperatures are extremely high, and unless the heat can be dissipated away almost at once, our estimates of the ratio of increase of density must be considerably reduced. The only mechanisms by which the compressed stream can lose heat seem to be those of radiation and ionization; these will now be considered.

9.7—Radiation of heat in the present case may take place by at least three distinct processes: (*i*) Continuous emission, (*ii*) line emission due to electron-captures, and (*iii*) line emission due to inelastic collisions.

The emission due to the encounter between an ion and an electron, giving rise to the spectra (*i*) and (*ii*), can be calculated on the basis of Kramers' theory of absorption, for it has been shown by E. A. Milne that this theory holds even in the case of a gas such as the photosphere of the Sun. The results obtained by Milne are discussed by A. S. Eddington* who finds that for singly-ionized calcium-atoms at a temperature of 6000°, and at a pressure of 100 dynes per cm^2, the mass-absorption or emission-coefficient, k', is about 150 c.g.s. This value seems to be uncertain to the extent of a factor 10. Since $k' \alpha\, N\, T^{7/2}$, for a gas whose density is N and temperature T, the appropriate value of k' is

$$k'=1{\cdot}37\ NT^{-7/2} \tag{123}$$

The emission per gm per second of a gas at temperature T is given by

$$4k'\sigma\, T^4 \tag{124}$$

where σ $(=5{\cdot}32\times10^{-5})$ here denotes Stefan's constant. Using the value of k' given by (123) the emission per cc per second is

$$j=4{\cdot}7\times10^{-28}\ N^2 T^{1/2} \text{ ergs} \tag{125}$$

This expression shows that the variation of the emission with temperature is only slight, the density being a far more important factor.

Some of the emitted radiation will be re-absorbed by the material and should be deducted from (125) to get the net emission; and it seems likely that the line emission may be cut off altogether by line absorption leaving only the continuous emission; this might reduce the value of j

*The internal constitution of the stars, 355-359 (1926).

by a factor of 10 or more, except, of course, in the surface-layers. Thus by using the expression (125) we shall over estimate the emission.

We shall continue to use the estimates for the density and velocity at the head of the stream deduced in the previous section for a calcium-stream.

Considering a column drawn in the stream 1 sq. cm. cross-section with its base in the surface of the stream and whose axis coincides with the axis of the stream, we have seen that the excess mass would be confined to a length of this column of about 10^4 cm with a mean density of about 10^{10} ions per cc when the front of the stream is at a distance of about 5 Earth-radii. Using these values and (125), and multiplying by 4π, it appears that the total emission from this length of the column cannot exceed 0.59 $T^{1/2}$ ergs per second. At the temperature 6000° this becomes equal to 46 ergs per second.

The rate at which kinetic energy is being transformed in this column is approximately

$$\frac{1}{2}\, N_\infty\, A m_H\, \dot{g}^3 \tag{126}$$

where $\dot{g}$ $(=w_\infty - \dot{z}_0)$ is the relative velocity of the particles at the back of the stream relative to the front surface. For a calcium-stream when $-Z=5$, $\dot{g} \sim w_\infty$, $N_\infty = 4000$, and substituting these values in (126) we find the rate at which kinetic energy is being transformed in the column is of the order of 10^5 ergs per second. This is 2000 times the rate of radiation of heat found above; this conclusion, that emission at the rate (125) cannot dispose of the transformed kinetic energy without a rise of temperature above 6000°, can be drawn less definitely but more simply, in the following way:

9.8—In order that matter may be heaped up at the front of the stream, the velocity in front must be decreased by an amount at least equal to the velocity of thermal agitation of the ions per second; that is, for a calcium-stream, by 10^5 cm/sec^2. Otherwise the matter would continually spread backwards with approximately this velocity as fast as it is heaped up. The region where this retardation will first take place depends on the initial density N_∞ of the stream. A rough calculation indicates that, for values of N_∞ lying between 10 and 1000, the front of the stream begins to be retarded by the magnetic field when within 1000 Earth-radii from the Earth. Taking $w_\infty = 10^8$, the front of the stream would be brought to rest in a time $\tau = 1000$ seconds, when it would have come within a distance of about 6 Earth-radii. The total mass accumulated would be of the order of $(1/2)\ N_\infty\ w_\infty\ \tau$ ions/cm^2, and if $N_\infty = 1000$, this is 10^{14} ions/cm^2. It is of the same order as the excess mass per sq. cm. found previously.

We cannot estimate in this way the thickness of the layer in which the greatest accumulation of matter occurs, but we can hardly suppose this to be smaller than the value of about 4 cm deduced in §8. Taking this to be of order of the thickness of the layer, the density at the front of the stream may be as great as 10^{13} ions/cc. Using this value of N, and taking the length of the column to be 4 cm instead of 10^4 cm (as was done in §9.7) the emission per sq. cm. of the surface would be 10^4 ergs/second instead of 46 ergs/second. Even this overestimate is less than the rate at which kinetic energy is transformed, namely, 10^5 ergs/second; thus

such radiation seems insufficient to prevent the temperature of the gas rising above 6000°.

9.9 -Emission by inelastic collisions will be to some extent counteracted by superelastic collisions; but if the density is low, for example less than 10^{13} ions/cc, the latter will be negligible; in fact, an inelastic impact can be effective in emitting the energy of collision only if the colliding corpuscles (two ions or an ion and an electron) apprcach within a distance comparable with the radius of the atom, 10^{-8} cm. The free-path is therefore of the order of $10^{15}/N$ cm, and the time of describing this path is $10^{15}/(NC)$ seconds, C being the relative speed of the colliding pair of particles. Taking for example $N=10^{10}$ ions/cc, $C=10^8$ cm/second, the above time becomes 10^{-3} second. The average life of an excited atom is of the order 10^{-8} second, so that as long as the density remains below 10^{13} ions/cc, the superelastic collisions may be neglected.

The ineleastic collisions of most importance will be those between ions and ions, causing radiation or ionization, and in either case disposing of some of the kinetic energy of the stream-motion without adding to the thermal energy. For these processes to occur, the colliding particles must approach to a distance of atomic dimensions—say 3×10^{-8} cm, corresponding to a mean free-path of about $10^{14}/N$ cm. The thickness of the layer, if, as calculated, this contains 10^{14} ions/cm^2 column, will also be $10^{14}/N$, so that in passing through the layer the incoming ions from behind will only make about one collision. Even if this is always effective in ionizing the particle collided with, the energy so lost, of the order 10 volts or 2×10^{-11} erg (say) is only a small fraction of the energy of motion of the incoming ion relative to the layer (e. g. if this relative velocity is $(1/2)\times 10^8$ cm/second, the excess energy for a *Ca*-ion is of order 10^{-7} erg). Thus if the incoming ion is to dispose of its surplus energy in the layer, it must be deflected (mainly by the magnetic field) and make many subsequent ionizing collisions. Meanwhile its kinetic energy, being no longer mainly in the stream-direction, counts in part as thermal energy of the layer. Thus it seems likely that the temperature of the layer must be raised, though ionizing collisions may dispose of an appreciable part of this kinetic energy. To the extent that such a rise occurs, the difficulty is enhanced as regards the value of N_∞ required for the stream to come within 5 radii of the Earth (consistently with the maintenance of $R_e \geq l_e$ at the front of the stream).

For example, suppose T is increased from 6000° to 100,000° (10^5 C). Since $R \propto T$ (115) shows that g remains unaltered if we increase N_∞ in the same ratio, so that the estimate of A^2/N_∞ given in §9.4 (namely 8×10^6) must be increased to about $1{\cdot}4\times 10^8$. For *Ca*-atoms this would make $N_\infty = 10^5$, corresponding to a density of emission at the Sun (allowing for geometrical broadening) of about 5×10^4, which in the light of present expectations seems excessive. Unfortunately the facts as to the emission at the Sun are as obscure as the working out of their terrestrial consequences is difficult.

In concluding this section we wish again to state that we are conscious of many unsatisfactory features in our present treatment, which exposes, rather than overcomes, the theoretical difficulties of the problem. We intend, however, to make further efforts after a solution, along any avenues that may seem open.

(To be continued)

REVIEWS AND ABSTRACTS

(See also pages 474, 478, and 482)

PACINI, D.: *I nuclei di condensazione e le polveri nell'atmosfera.* Roma, Mem. Uff. Met. Geofys., Ser. 3, v. 3, 1930. 20 pp.

The investigations described in this paper were carried out at Bari, on the Adriatic coast of Italy, a city bounded on two sides by the sea. The observations were made at a point about 650 meters from the shore where breezes from the sea predominate. The apparatus used consisted of an Owens dust-counter and an Aitken nuclei-counter, the latter having been furnished by the maker G. Schulze, of Potsdam, with certain modifications suggested by Prof. Lüdeling. The results of the investigations are summarized by the author as follows:

"The work exhibits the important rôle played by the Aitken nuclei in the phenomena which take place in the atmospheric strata nearest the ground in comparison with the much weaker effects, in general, of the Owens dust-particles which, on the other hand, appear without exception in rather limited numbers. The mean number of condensation-nuclei at Bari resulting from almost daily observations, made from November 1928 to July 1929, is 33,400 per cc, whereas that of the dust-particles is hardly 60 per cc.

"The measurements do not reveal a definite relation between dust-particles and nuclei; the variations between the instantaneous and periodical numerical values are for the most part diverse; however, it must be remembered that, in the conditions under which the investigations were conducted, there are causes producing nuclei and dust-particles other than the common origin of combustion. Observations made on the shore with breeze from the sea indicate that salt from the sea does not influence appreciably the number of dust-particles while there is a contribution to nucleation of marine origin. The transparency of the atmosphere depends principally on the number of nuclei of condensation present and the relative humidity. It would appear that the nuclei of marine origin are particularly adapted for determining the state of haze. Some experiments seem to furnish confirmation that the condensation of vapor does not take place on dry dust-particles."

It should be pointed out that the author does not claim that the very high values for nuclei of condensation found at Bari are to be attributed mainly to marine origin. In fact, the value (2,800 per cc) obtained on a dike, some 700 meters seaward from the present breakwater, with breeze coming from the sea, July 26, 1929, and those obtained on the reef of S. Cataldo, May to July, 1929, (mean 3,720 per cc) are in fair agreement with the determinations made under oceanic conditions, during the seventh cruise of the *Carnegie* in 1928-1929, at 755 stations in the Atlantic and Pacific oceans which gave a mean value of 2,200 nuclei per cc, and with measurements made in 1928 on the Byrd Antarctic Expedition at 32 stations in the Pacific Ocean, which yielded a mean value of 4,320 nuclei per cc. It should also be borne in mind that the fact that nuclei were obtained by the author presumably under sea-conditions can hardly be advanced as proof that they were of marine origin, since a certain number of nuclei would be expected, even over the ocean, on account of the general diffusion from land-sources. In his paper, the author refers to results obtained at Dublin, Irish Free State, over an extended period, as showing a mean of 23,800 nuclei per cc. Recent measurements made at Washington, D. C., have given an average value of approximately 30,000 nuclei per cc. It is at once apparent that the value 33,400 obtained at Bari is of the same order of magnitude as the values for Dublin and Washington in which cases the high values must certainly be attributed to industrial and domestic activities. It seems, therefore, probable that the nuclei determinations at Bari which is a port of considerable importance, reflect the characteristics of the polluted atmospheric conditions prevailing in the vicinity of urban activities.

H. D. HARRADON

DIE HÖHE DER POLARLICHTER UND DIE TEMPERATUR DER OBEREN ATMOSPHÄRE*

Von G. Angenheister

Inhalt—Die verschiedenen Erscheinungen, die zur Bestimmung der Temperatur der Atmosphäre über 35 km Höhe bisher benutzt wurden, werden besprochen. Sodann wird als neuer Weg hierzu die Verschiebung der Absorptionshöhe der Polarlichter beim Übergang vom Tag zur Nacht benutzt. Es wird für die helle und dunkle Atmosphäre eine mögliche Temperaturverteilung mit der Höhe angegeben. Diese führt für eine durchgemischte Atmosphäre zu einer Massenverteilung, die den beobachteten Absorptionshöhen der Polarlichtstrahlen in der dunkeln und hellen Atmosphäre gerecht wird; sodass nämlich über den beim Wechsel vom Tag zur Nacht herabgesenkten Absorptionshöhen gleiche Massen erhalten bleiben. Danach müsste bei Tage die Atmosphäre in der Höhe von 100-200 km auf etwa 1000° abs. (darüber weniger) erhitzt werden und sich dadurch stark ausdehnen; bei Nacht kühlt sie sich in diesen Höhen wieder auf etwa 300° abs. ab und sinkt in sich zusammen.

Aus aerologischen Aufstiegen ist die Temperatur der Atmosphäre bis zu etwa 30 km Höhe bekannt. Danach besteht in der Troposphäre ein mittlerer Temperaturgradient von 6° km. Darüber, in der Stratosphäre, herrscht von 10-30 km Höhe, wahrscheinlich sogar bis 35 km Höhe in erster Annäherung eine fast konstante Temperatur von etwa 220° abs., oder doch nur ein geringer Ansteig von 1°/km.

Zur Bestimmung der Temperatur der Höhen über 35 km wurden bisher folgende Erscheinungen benutzt: (1) die Schallausbreitung; (2) die Absorption im Ozon; (3) das Aufleuchten und Erlöschen der Meteore; (4) der Gehalt an Helium in der Atmosphäre; und (5) die Verbreiterung der grünen Polarlichtlinie.

Ich möchte im folgenden unter II eine weitere Möglichkeit erörtern, nämlich die Absorptionshöhe der Polarlichter. Doch soll vorher kurz unter I angegeben werden, zu welchen Temperaturen für Höhen über 35 km die oben angegebenen Erscheinungen führen.

I—*Bisherige Wege zur Ableitung der Stratosphärentemperatur*

(1) *Die Schallausbreitung*. Die Studien über die Schallausbreitung gewannen eine sichere Grundlage erst durch die instrumentellen Aufzeichnungen, die bei planmässig angelegten Explosionen gewonnen wurden. Auf Grund dieser instrumentellen Aufzeichnungen konnte ich 1925 die erste Laufzeitkurve des normalen und anormalen Schalles bis über 300 km hinaus aufstellen[1]. Ich konnte daraus auch schon die Scheitelhöhe und Scheitelgeschwindigkeit des anormalen Schalles zum ersten Mal auf Grund experimenteller Daten zu 37 km und 350 m sec angeben. Spätere Bearbeitungen der Schallbeobachtungen von E. Wiechert, B. Gutenberg, O. Meisser, P. Duckert, und anderen ergaben meist Scheitelhöhen zwischen 35 und 50 km und Scheitelgeschwindigkeiten zwischen 340-360 m/sec.

Die Schallgeschwindigkeit in Gasen $c=\sqrt{\kappa BT}$ enthält das Verhältnis der spezifischen Wärmen, κ, die spezifische Gaskonstante für das betreffende Gas B und die absolute Temperatur T. Nimmt man an, dass in allen Höhen der Atmosphäre die Zusammensetzung der Luft infolge Durchmischung unverändert ist, so kann man B und auch wohl κ als Konstanten ansehen, und c ist nur abhängig von T.† Die Scheitel-

*This article was prepared for the Bauer Memorial Number of the Journal (September 1932) but was received too late to be included in that number.—*Ed.*

†Wenn in der Umkehrhöhe (40 km) alle Gase der Luft einatomig wären, wass nicht angenommen werden kann, würde κ und damit v, letzteres um fast 10%, wachsen.

[1]Zs. Geophysik, 1, 314-327 (1924-1925).

geschwindigkeiten der Schallstrahlen verlangen dann für die Scheitelhöhen zwischen 40 und 50 km eine Temperatur von 300° bis 340° abs. Zwischen etwa 35- und 40-km Höhe muss danach ein plötzlicher Anstieg der Temperatur um mindestens 20° pro km erfolgen. Dieser Temperaturanstieg muss auch bei Nacht ziemlich unverändert bestehen, da auch bei Nacht die anormale Schallausbreitung fast ebenso wie bei Tage erfolgt.

(2) *Die Temperatur der Ozonschicht*—Die ultraviolette Sonnenstrahlung und die Elektronenstrahlung der Sonne bilden in grossen Höhen (etwa über 40 km) Ozon. Die Sonnenstrahlung auch grösserer Wellenlänge wird im Ozon selektiv absorbiert. Bei Strahlungsgleichgewicht muss die ausgestrahlte Energie gleich der absorbierten sein. Ausstrahlung und Absorption erfolgen auf den gleichen Wellenlängen; dabei entspricht die Energieverteilung der Ausstrahlung der des schwarzen Körpers. Erfolgt also die Ausstrahlung wie beim Ozon zu einem grossen Teil im Ultraviolett, so muss, um Strahlungsgleichgewicht herbeizuführen, die Temperatur verhältnismässig hoch ansteigen, mindestens aber bis $T = 0.294/\lambda_{max}$, worin λ_{max} die längste selektive Emissionswellenlänge ist. Ist ausserdem Wasserdampf in diesen Atmosphärenschichten vorhanden, so kann ein grosser Teil der Energie auch bei grösseren Wellenlängen ausstrahlen und Strahlungsgleichgewicht wird schon bei niedrigerer Temperatur erreicht als ohne Wasserdampf. Bei völliger Durchmischung der Stratosphäre ist der höchstmögliche Wasserdampfgehalt in der Stratosphäre prozentual für alle Höhen der gleiche. In einer sehr interessanten Studie hat C. H. Gowan[2] für diesen Fall die Temperatur als Funktion der Höhe berechnet. Zwischen 40 und 160 km findet er als Maximaltemperaturen je nach den immerhin möglichen Annahmen über den Ozongehalt 600°-900° abs.

(3) *Aufleuchten und Erlöschen der Meteore*—Aus der Beobachtung der Geschwindigkeit, der Höhe des Aufleuchtens und Verlöschens der Meteoriten schliessen Lindemann und Dobson auf die Dichte und Temperatur der Atmosphäre in diesen Höhen. Danach sollen in 50 km 300° bis 350° abs. herrschen. Sonst würden die Geschwindigkeiten, die nach den Beobachtungen bis 12 km/sec herabgehen, nicht ausreichen um das beobachtete Aufleuchten hervorzurufen. B. Gutenberg[3] hat dann später die Ergebnisse der Beobachtungen an Meteoriten unter Verwendung der Theorie von Lindemann und Dobson näher diskutiert. Hiernach stehen die Dichten, die man für Höhen von 50-100 km aus den Beobachtungen der Meteoriten ableitet, am besten in Einklang mit den Dichten einer durchgemischten Atmosphäre (mit der Höhe etwas abnehmend Sauerstoff und langsam zunehmend ein leichtes Gas) von 500° bis 1000° C.

(4) *Der Gehalt an Helium in der Atmosphäre*—Am Erdboden beträgt der Heliumgehalt höchstens 0.0004 Volumprozent; dem entspricht in einer homogenen Atmosphäre eine Schichthöhe von etwa 3 cm *He*. H. Jeffreys[4] hat darauf hingewiesen, dass eine Schicht von 100 m saueren radioaktiven Gesteins durch Denudation zerkleinert diese *He*-Menge liefern kann, wenn das Gestein bei der Denudation 160 Millionen Jahre alt war; selbst dann, wenn die Hälfte des entstandenen Heliums im Gestein occludiert bleibt. Tatsächlich ist aber seit Erstarrung der

[2] Proc. R. Soc., **120**, 655-669 (1928); **128**, 531-550 (1930).

[3] B. Gutenberg, Handbuch der Geophysik, **9**, 15-21 (1932).

[4] The Earth 313 (1929).

Erdrinde eine vielmals längere Zeit verflossen und ausserdem eine vielmals dickere Schicht radioaktiven Gesteins durch Denudation aufgearbeitet, sodass ihr Heliumgehalt in die Luft einströmen konnte. Der Heliumgehalt der Atmosphäre müsste danach viel grösser sein. Da eine chemische Bindung des Heliums unwahrscheinlich ist, muss man annehmen, dass das Helium die Erdatmosphäre nur durchströmt und aus ihr in den Weltraum entweicht.

Die Grenzgeschwindigkeit, die nötig ist, um aus dem Schwerefeld der Erde zu entkommen, ist $v=\sqrt{2\ gr}=11$ km/sec (g=Schwerebeschleunigung, r=Erdradius). Beträgt die mittlere molekulare Geschwindigkeit $\bar{c}$ eines Gases nur etwa 1/4 davon, also nur etwa 2.5 genauer 2.6 km/sec, so wird nach dem Maxwell'schen Verteilungsgesetz in einer Million Jahren die Grenzgeschwindigkeit von 11 km/sec doch schon so oft überschritten, dass das Gas praktisch vollkommen aus dem Erdfeld entweicht. 2.6 km/sec wird als mittlere molekulare Geschwindigkeit des Heliums bei einer Temperatur von rund 1000° abs. erreicht. $\bar{c}=\sqrt{(8/\pi)\ BT}$, worin B die specifische Gaskonstante des betreffenden Gases bedeutet. (Für 10^3 Jahre beträgt die entsprechende Geschwindigkeit 2.9 km/sec; für 10^9 Jahre 2.3 km/sec). Damit das Helium sich nicht in der Atmosphäre anreichert, muss seine Temperatur in den oberen Schichten von der Grössenordnung 1000° abs. sein.

(5) *Die Verbreiterung der grünen Polarlichtlinie.* Die grüne Polarlichtlinie ($\lambda=5577$) ist am Nachthimmel und in allen Breiten sichtbar, auch ohne besondere Polarlichtentfaltung, dann allerdings nur schwach. An dieser stets sichtbaren grünen Linie hat Babcock mit dem Interferometer genaue Messungen der Wellenlänge λ und ihrer Breite $\triangle\lambda$ vorgenommen. Er fand $\lambda=5577.350$ und $\triangle\lambda=0.035\pm0.001\mathring{A}$. Es ist anzunehmen, dass diese Verbreiterung $\triangle\lambda$ dem Dopplereffekt infolge der Wärmebewegung des Gases zuzuschreiben ist. Nach Laboratoriumsversuchen (z. B. von Cario mit Konkavgitter) muss die grüne Linie ($\triangle\lambda=5577$) dem Sauerstoff zugeschrieben werden. Es ist nicht sicher, ob diese Linie dem O-Molekül oder metastabilen O-Atomen zugehört. Die Temperatur des O-Gases folgt dann aus $\triangle\lambda=0.82\times10^{-6}\sqrt{T/M}$. Für $M=16$ bezw. 32 (O) und für $\triangle\lambda=0.035$ Å wird $T=900°$ bezw. 1800° abs.

II—*Die Absorptionshöhe der Polarlichter und die Temperatur der Stratosphäre*

(1) *Absorptionshöhe und Natur der Strahlen*—Die Polarlichter werden durch eine Korpuskularstrahlung hervorgerufen. Sie sind uns nur von der Nachtseite der Erde aus sichtbar. Von dort aus sehen wir sie sowohl im unteren dunkeln Teil der Atmosphäre, als auch im höheren Teil, der noch im Sonnenlicht liegt. Das wesentlichste Ergebnis der Messung der Höhe der Polarlichter ist folgendes: Nach den Beobachtungen von C. Störmer liegen im lichtbeschienenen Teil der Atmosphäre die Polarlichter zwischen 200- und 1000-km Höhe; im dunkeln Teil der Atmosphäre zwischen 80 und 400 km.

Die Ionisation der Atmosphäre ändert sich, wie die Beobachtung der drahtlosen Telegraphie zeigt, beim Uebergang vom Tag zur Nacht. Damit kann auch eine Aenderung der Höhenlage der Polarlichter verbunden sein. Wahrscheinlicher ist indessen, dass sie zum grössten Teil durch eine Aenderung der Massenverteilung in der Atmosphäre veran-

lasst wird. Eine electrostatische Aufladung der Atmosphäre bei Tage könnte sehr wohl durch die electrostatische Abstossung eine Auflockerung der Atmosphäre herbeiführen. Doch wissen wir sehr wenig sicheres hierüber. Die nächstliegende und wahrscheinlichste Erklärung bleibt wohl eine Massenverlagerung durch Temperaturänderung. Diese Möchlichkeit soll hier qantitativ betrachtet werden. Gegen eine solche thermische Auflockerung (und ebenso gegen eine electrostatische) lässt sich einwenden, dass durch diese Vertikalbewegung der electrisch leitenden Atmosphäre im Magnetfeld der Erde in ihr Induktionströme entstehen müssen, deren magnetische Wirkung bisher noch nicht nachgewiesen wurde. Doch lässt sich die Grössenordung dieser Wirkung nicht so sicher überschauen. Jedenfalls scheint es mir nützlich, die Grösse der Temperaturänderung zu bestimmen, die notwendig ist, um diejenige Höhenänderung der Polarlichter zu erklären, die tatsächlich beobachtet wird. Es muss beim Übergang vom Licht zum Dunkel ein Zusammenschrumpfen der Atmosphäre stattfinden. Im belichteten Teil ist noch in 1000 km Höhe genügend Atmosphäre vorhanden um Leuchterscheinungen zu ermöglichen, und in 200 km reicht die oberhalb lagernde Masse aus, die eindringenden Strahlen vollständig zu absorbieren. (Letzteres gilt natürlich nicht für rückläufige Bahnen, geodätische Linie; sondern nur für solche, die in erster Annäherung als gradlinig anzusehen sind.) Im dunkeln Teil der Atmosphäre genügt dagegen erst in 400 km Höhe die Dichte um sichtbare Leuchterscheinungen zu erzeugen, und erst in 80 km erzwingt die überlagernde Masse eine vollständige Absorption. Natürlich variieren diese Grenzen von Fall zu Fall mit dem Incidenzwinkel und mit der Geschwindigkeit der Strahlung. Indessen erlauben sie doch einen Schluss auf die Temperaturänderung der Atmosphäre beim Übergang vom Tag zur Nacht.

Die Höhe, in der eine in die Atmosphäre eindringende Strahlung absorbiert wird, hängt ab von der Natur der Korpuskularstrahlung, also von $(m/e)v$, und von der bis zu dieser Höhe durchlaufenen Masse. Diese lässt sich bei senkrechtem Eindringen aus dem dort herrschenden Druck berechnen. Die über einem bestimmten Niveau lagernde Masse lässt sich pro cm^2 als Höhe einer Quecksilbersäule oder als Höhe P_n einer äquivalenten, gleich schweren, Säule Normalluft bei ($T=273°$ abs.; $p=760^{mm}$Hg) angeben. Mit diesem P_n kann man vergleichen bei α-Strahlen die experimentell bestimmte Reichweite R in Normalluft, bei Kathoden- und β-Strahlen die Grenzdicke X in Normalluft, nach deren Durchlaufen die Geschwindigkeit v der β-Strahlen auf molekulare Geschwindigkeit abgesunken ist. Die folgende Tabelle enthält für einige Strahlenarten die Geschwindigkeit v gemessen in Teilen der Lichtgeschwindigkeit c und die zugehörigen Werte von $(m/e)v$, sowie die Werte von R bezw. X. Für m ist nicht die Ruhemasse m des Electrons zu setzen, sondern $m=m_0c\,[1-(v/c)^2]^{-1/2}$

Strahlen	v/c	$(m/e)v$	X in cm	R in cm
Kathoden	0.2	300	0.38	.
	0.3	500	2.2	.
β	0.9	4000	270	..
	0.99	14000	1300	...
α	0.067	40000	....	7.4

Die hier angegebenen Strahlenarten vermögen somit bis zu den Höhen hinabzudringen, in denen das Luftäquivalent der überlagernden Masse in cm gemessen gleich den entsprechenden Werten von X bezw. R ist.

(2) *Temperatur und Massenverteilung in der dunkeln Atmosphäre*

Der Luftdruck und damit auch das Luftäquivalent lässt sich als Funktion der Höhe aus der Zustandsgleichung $pv=BT$ ableiten. Hierin ist B eine Konstante, die für jedes Gas ihren besonderen Wert besitzt. Ist die Vertikalbewegung in der Atmosphäre gering, so stellt sich Diffusionsgleichgewicht ein. Dann baut in einem Gasgemisch jedes Gas unabhängig von den anderen seine eigene Atmosphäre auf (Dalton'sches Gesetz). Dadurch ändert sich mit der Höhe die Zusammensetzung. In grossen Höhen herrschen dann die leichten Gase vor. Je nach den Annahmen über den Gehalt an leichten Gasen (H und He) erhält man nach den Rechnungen von Milne-Chapman über 200 km eine praktisch reine He-Atmosphäre oder nach den Rechnungen von Störmer-Jeans über 150 km eine H-He-Atmosphäre. Beides widerspricht den Erfahrungen, denn das Polarlichtspektrum in diesen Höhen zeigt nie H- und He-Linien, sondern nur N- und O-Linien.

Wird die Atmosphäre aber durch Vertikalbewegungen dauernd durchgemischt, so kann für alle Höhen bis zu denen die Durchmischung gelangt, die gleiche Zusammensetzung bestehen, wie am Boden, also fast eine reine N-O-Atmosphäre. Die Durchmischung verhindert die Einstellung des Diffusionsgleichgewichtes. Nur dieser Fall soll hier betrachtet werden.

Für eine polytrope Atmosphäre gilt

$$p_1/p_2=(T_2/T_1)^{n/(1-n)}$$

worin $n=1/[1+B(\triangle T/\triangle h)]$; $h_2-h_1=(T_2-T_1)\ (\triangle h/\triangle T)$. Für eine isotherme Atmosphäre ist

$$\log\ \mathrm{nat}\ (p_1/p_2)=(h_2-h_1)/BT_1$$

Hierin sind p_1 und p_2 die Drucke, T_1 und T_2 die absoluten Temperaturen im Niveau h_1 und h_2.

Betrachten wir nun zunächst den dunkeln Teil der Atmosphäre. Wir setzen eine wahrscheinliche, einfache Temperaturverteilung mit der Höhe (Fig. 1) für die dunkle Atmosphäre (I) voraus und berechnen die zugehörige Druckverteilung. Daraus folgt die Höhe der Säule Normalluft P_n in cm, die diesen Drucken in den verschiedenen Niveaus entspricht. Der Logarithmus dieser Höhe Normalluft P_n (in cm) ist in der Figur 2 als Funktion der Niveauhöhe (in km) eingetragen. Die hierbei gewählte Temperaturverteilung für die dunkle Nachtseite der Atmosphäre (I) ist folgende: Die Zusammensetzung sei in allen Höhen konstant.

0-10 km polytrop, $\triangle T/\triangle h=-0°.6$ per 100 m; $T_0=283°$ abs.
10-35 km isotherm; $T_{10\text{-}35}=223°$
35-43 km polytrop; $\triangle T/\triangle h=+1°$ per 100 m; $T_{35}=223°$; $T_{43}=303°$
43-400 km isotherm; $T_{43\text{-}400}=303°$

Bis 35 km sind hierbei die aerologischen Ergebnisse zugrundegelegt, von 35-43 km wurde Temperaturanstieg auf 303° angenommen, da auch bei Nacht der anormale Schall beobachtet wurde. Darüber als einfachste Annahme Isothermie (Fig. 1).

Die oben angegebenen Werte für X sind als Linien parallel der Höhenaxe in die Figur 2 eingetragen. Die Schnittpunkte zwischen

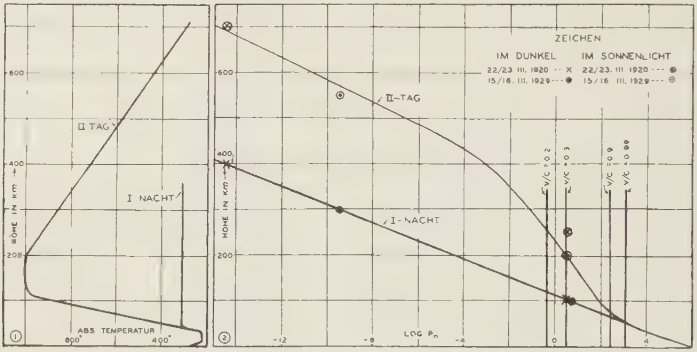

FIG. 1 UND 2—(1) Absolute Temperatur als Funktion der Höhe; (2) Logarithmus des Druckes P_n in cm Normalluft als Funktion der Höhe in km. (Für die dunkle Atmosphäre I sind die untere und obere Grenze der Polarlichter als Schnitt der Niveaulinie mit der P_n-Kurve I eingetragen; für die helle Atmosphäre II sind sie demselben P_n wie in I zugeordnet. Sie fallen dann nahezu auf die P_n-Kurve II.)

diesen Linien und der Kurve I lehren, dass die Absorptionsgrenze der Kathodenstrahlen ($v/c=0.2$ bis 0.3) in der dunkeln Atmosphäre (I) zwischen 105 und 120 km liegt, während die schnelleren β-Strahlen zu tief, bis 60 und 50 km herabreichen. Andere Eigenschaften der Polarlichter deuten an, dass sie durch Electronen von etwa $v/c=0.25$ erzeugt werden.

(3) *Änderung der Höhe der Polarlichter beim Übergang von Nacht zum Tag*—Die Höhe von Polarlichtstrahlen im dunkeln und sonnenbeschienenen Teil der Atmosphäre wurde von C. Störmer[5] und seinen Mitarbeitern besonders an zwei Terminen eingehend bestimmt am 22/23. März 1920 und am 15/16. März, 1929.

Ende	Im Dunkel (I)		Im Sonnenlicht (II)	
	22/23. März, 1920	15/16. März, 1929	22/23. März, 1920	15/16. März, 1929
	km	*km*	*km*	*km*
Unteres . . .	100	100	250	200
Oberes	400	300	700	550

Die untere Grenze wird beim Übergang von dunkel zu hell um 100-150 km gehoben, die obere um 250-300 km. Die Lage der oberen und unteren Enden der Polarlichtstrahlen im Dunkel sind in die Figur 2 eingetragen. In der dunkeln Atmosphäre liegen die unteren Enden in den beiden oben angeführten Fällen bei 100 km ($\log P_n=0.5$); die obere bei 300 und 400 km ($\log P_n=-9.5$ bezw. -14.5). Es ist nun wahrscheinlich, dass im sonnbeschienenen Teil der Atmosphäre die eindringenden Polarlichtstrahlen dieselben Dichten antreffen müssen wie in der dunkeln, um Leuchterscheinung zu erzeugen, und ebensoviel Masse durchlaufen müssen, um schliesslich abgebremst zu werden. Dann muss für das obere Ende der

[5]Ergebnisse der kosmischen Physik, 1, 17-27 (1931).

Polarlichter im sonnenbeschienenen Teil oberhalb 700 bezw. 550 km der Druck und damit die Dichte ebenso gross sein, wie im dunkeln Teil oberhalb 400 bezw. 300 km, und für das untere Ende im sonnbeschienenen oberhalb 200 bezw. 250 ebensoviel Masse liegen wie im dunkeln Teil oberhalb 100 km.

(4) *Temperatur und Massenverteilung in der hellen Atmosphäre* – Da dies Zuzammenschrumpfen der Atmosphäre beim Übergang vom Tag zur Nacht erfolgt, ist anzunehmen, dass es durch Temperaturänderung veranlasst wird. Eine Druckverteilung mit der Höhe, die den obigen Bedingungen genügt, ist, wie die Figur 2 zeigt, offenbar durch die Kurve II dargestellt, die folgender Atmosphäre II in Figur 1 entspricht: Die Luft habe wieder in allen Höhen eine konstante Zusammensetzung.

0-35 km wie bei I
35-113 km polytrop, $\triangle T/\triangle h = +1°$ per 100 m; $T_{35} = 223°$; $T_{113} =$ 1000° abs.
113-200 km isotherm; $T_{113\text{-}200} = 1000°$
200-700 km polytrop; $\triangle T/\triangle h = -0°.14$ per 100 m; $T_{200} = 1000°$, $T_{700} = 300°$

Man erkennt aus der Figur 2, dass für diese beiden Atmosphären I (dunkel) und II (sonnenbeschienen) über den Niveaus der unteren und auch der oberen Grenzen der Polarlichtstrahlen nahezu gleiche Luftmassen lagern. Danach erwärmt sich die Atmosphäre in der Höhe von 100-200 km beim Übergang von Nacht zum Tag von 300° auf 1000° abs.; oberhalb 200 bis zu 700 km ist die Erwärmung geringer; in 700 km herrscht wie zur Nacht 300°. Dies kann natürlich nur eine ganz rohe Annäherung sein. Um also die höhere Lage der Polarlichter im sonnenbeschienenen Teil der Atmosphäre zu erklären, ist ein Anwachsen der Temperatur in grossen Höhen während des Tages auf 1000° notwendig. Das ist aber eine Temperatur, die auch aus den anderen Beobachtungen wahrscheinlich wurde. Diese Erwärmung bezw. Abkühlung muss in wenigen Stunden erfolgen.

(5) *Die Abkühlungsgeschwindigkeit*—E. A. Gowan glaubt, im Gegensatz zu Maris[6] dass die oberen Schichten sich nach Sonnenuntergang sehr langsam nur um etwa 2° pro Stunde abkühlen. Die Schätzung basiert auf der Annahme, dass die ganze Luftmasse über 40 km sich in gleicher Weise abkühlt. Ich glaube indessen, man muss berücksichtigen, dass die höheren, dünneren Schichten sich schneller und höher erwärmen, als die tieferen und sich auch schneller abkühlen.

Die Absorption des Ozons im Ultraviolett ist sehr hoch, der Absorptionskoeffizient steigt bis $\alpha = 150$. 0.3 cm Ozon von Normaldruck und Temperatur absorbieren im Ultraviolett etwa 5% der gesamten Sonnenenergie; also an der Tagseite in den wolkenlosen Höhen über 40 km im Mittel etwa 0.05 gr/cal per min/cm². Die geringe Menge von 0.001 cm Ozon absorbiert im Ultraviolett aber schon etwa 0.005 gr/cal per min/cm². Das bedeutet, bei Abnahme der vom Sonnenlicht durchsetzten Ozonschicht auf 1/300, sinkt die absorbierte Energie nur auf 1/10. Im Infrarot und im Sichtbaren ist dagegen die Absorption des Ozons sehr klein, $\alpha < 1$. Das hat zur Folge, dass die Temperatur

[6]Terr. Mag., 33, 233-235 (1928).

am Tage anwächst, und zwar um so mehr, je höher die Schichten liegen, die noch Ozon enthalten.

Es wird nun angenommen, dass der gesamte Ozongehalt der Atmosphäre 0.3 cm beträgt und über 40 km Höhe liegt. Ferner sei der Partialdruck des Ozons auch in grösseren Höhen proportional dem 0-Druck. Dann ist in der belichteten Atmosphäre II oberhalb 130 km Höhe noch ungefähr 0.001 cm Ozon, und seine Absorption des Sonnenlichtes beträgt also 0.005 gr/cal per min/cm². Der Luftdruck in 130 km Höhe beträgt in der belichteten Atmosphäre etwa 0.03 gr; und eine Zufuhr oder Entzug von 0.007 gr/cal per min/cm² ist dort notwendig, um 1° Temperaturerhöhung bezw. 1° Temperaturerniedrigung zu erhalten. Nimmt man nun an, dass angenähert Strahlungsgleichgewicht herrscht, so wird durch Abschirmen der Sonne beim Übergang vom Tag zur Nacht die Temperatur mit der Geschwindigkeit von etwa $0.005/0.007 = 0^\circ.7$ pro Minute sinken, oder um 42° pro Stunde. Natürlich ist dies nur eine ganz grobe Annäherung. Da die Wärmekapazität der Luft proportional mit der Dichte sinkt, diese aber schneller als die absorbierte Sonnenenergie, so muss die Abkühlungsgeschwindigkeit mit der Höhe zunehmen, ebenso die Erwärmungsgeschwindigkeit beim Übergang von Nacht zum Tag. Man kann also in den Höhen von 100-200 km im Laufe des Tages mit einer Temperaturschwankung von mindestens einigen hundert Grad rechnen.

Natürlich wird sich das Gas beim Zusammensinken erwärmen und dies die Abkühlung durch Ausstrahlung verzögern. Die Geschwindigkeit der Abkühlung wird dadurch vielleicht auf die Hälfte sinken.

(6) *Zusammenfassung*—Nach dem hier aufgestellten sehr groben Schema enthalten bei Tage die Luftschichten oberhalb 130 km, deren sehr geringe Masse nur 3/100 gr beträgt, genügend Ozon (1/1000 cm) um ein Zehntel der überhaupt vom Ozon verschluckten Sonnenenergie zu absorbieren, nämlich 0.005 gr/cal per min/cm². Sie haben sich daher beim Übergang von Nacht zum Tag um einige hunderte von Graden, vielleicht auf 1000° abs., erhitzt und dabei stark ausgedehnt. Beim Einbruch der Nacht kühlen sie sich ebenso schnell ab und sinken wieder zusammen. Der Strahlungsaustausch mit tieferen, weniger warmen Schichten und die thermodynamische Abkühlung und Erwärmung beim Ausdehnen und Zusammensinken verzögern diesen Vorgang vielleicht um Stunden, ohne jedoch die Grössenordnung der Temperaturschwankung zu ändern. Tiefere Schichten sind geringeren Temperaturschwankungen unterworfen. In den Höhen, in denen das Aufleuchten der Meteore verschwindet, und in denen Schallstrahlen zur Erde zurückgebogen werden (50-40 km), mögen die täglichen Temperaturschwankungen nur nach Zehnern von Graden zu bemessen sein. In einer Atmosphäre dieser Art müssen sich beim Übergang vom Tag zur Nacht die Absorptionshöhen der Polarlichter in der oben beschriebenen Weise verschieben, während für die Vorgänge der Schallausbreitung und des Aufleuchtens der Meteore keine grossen Änderungen zu erwarten sind.

Ein naheliegender Einwand gegen die obigen Ausführungen ist natürlich die Frage, ob in den grossen Verdünnungen der hohen Atmosphäre die hier benutzten Gasgesetze noch angewandt werden dürfen.

Geophysikalisches Institut,
Göttingen, Deutschland, August 1932

SOURCES OF ERRORS IN THE DETERMINATION OF THE POTENTIAL GRADIENT OF THE EARTH'S ELECTRIC FIELD

By A. G. McNish

Abstract—Potential-gradient data are likely to be misinterpreted if space-charge distributions are not given appropriate consideration. The magnitude of these effects is investigated for various space-charge conditions. The errors which enter into reduction-factor determinations from this source are calculated, and conditions for reducing this error to a minimum are outlined. Equations are developed for the effect of finite space-charge distributions on the quantity V/h. The equations show that if the horizontal extent of the space-charge layer is several times its thickness, errors introduced by considering its horizontal extent as very great are negligible.

(1) *Consideration of a homogeneous space-charge layer of infinite horizontal extent*—The potential difference between a collector and the Earth divided by the distance from the collector to the zero-potential surface is used as a measure of the potential gradient in regions where the equipotential surfaces are horizontal. In what is to follow the effect of various space-charge distributions will be investigated with a view to explaining some of the peculiar phenomena associated with the potential gradient as measured in this way.

The simple equation

$$\mathrm{d}V/\mathrm{d}h=-4\pi\ (\sigma+\rho h)$$

for the relationship between space-charge, surface-charge, and potential gradient at considerable heights, as given by numerous investigators, is equally applicable near the Earth's surface. Although itself basically correct, this equation frequently leads to erroneous concepts when used to explain various gradient phenomena[1], due chiefly to an incorrect interpretation of σ.

To avoid this fallacy the equation will be modified to the following form:

$$\mathrm{d}V/\mathrm{d}h=-4\pi\ (\sigma_0+\sigma_i+\rho h) \tag{1}$$

in which ρ is the mean space charge density in the atmosphere up to a height h, σ_i, the surface charge induced by ρh, and σ_0, the surface charge of the earth due to all causes other than the induction of ρh, each term having, of course, its appropriate sign. This equation will now be developed to show the effect which each term has upon the potential difference between the collector and the ground. Inasmuch as this discussion will be limited to local effects we may regard the Earth in that region under consideration as a charged conductor of infinite thickness and infinite horizontal extent. The development of equation (1) which follows will then hold as long as the vertical extent of the space-charge is small as compared with its horizontal extent. The magnitude of errors

[1]Simpson (Brit. Antarc. Exp. 1910-1913, Meteorology, **1**, 311) attempts to explain negative gradients which he observed in Antarctica as due to a positive space-charge (positively charged ice-particles) layer between the collector and the Earth on the basis that this layer would counteract the normal negative surface-charge of the Earth. Inasmuch as the Earth, and even the snow covering, according to Simpson, is a fairly good conductor, this positive layer would induce a negative surface-charge equal to it in magnitude. Thus the effect of the space-charge would be nullified, and as shall be shown later, the gradient above this positively charged layer would be that due to the normal surface-charge of the Earth alone. Effects such as Simpson describes can be explained only by the presence of large quantities of negative space-charge without the concomitant positive space-charge of which he speaks.

introduced by the assumption of infinite extent of the space-charge layer will be investigated later.

Since, as has been pointed out, it is commonly assumed that the quotient of the potential difference and the distance between the collector and the ground is the potential gradient, an integration of equation (1) is necessary. To make the case all-inclusive, let the space-charge density be a function of the height, say $f(h)$, the integral of which is $F(h)$. The induced surface charge, σ_i, then becomes $-F(h)$, in which h is the distance of the collector from the zero-potential surface.

Integrating equation (1) between the limits 0 and V_h for V, and 0 and h for h, remembering that $\sigma_i = -F(h)$ gives

$$V/h = -4\pi\ [\sigma_0 - F(h) + G(h)/h] \qquad (2)$$

where $G(h) = \int F(h)dh$, which is commonly taken to be the gradient given by the collector. Certain limiting conditions will now be imposed, and the character of the expression resulting therefrom will be investigated.

Case 1· If the space-charge is positive and homogeneous, of density ρ throughout the region below the collector and σ_0 is negative, then since $F(h) = \rho h$

$$G(h) = \int_0^h F(h)dh = \int_0^h \rho h dh = \rho h^2/2 \text{ and}$$

$$V/h = 4\pi\ (\sigma_0 + \rho h - \rho h/2) = 4\pi\ (\sigma_0 + \rho h/2) \qquad (2a)$$

Now it may be seen from equation (1) that under these conditions, since $\sigma_i = -F(h) = -\rho h$, the total space charge and the surface charge, σ_i, induced by it will be equal in magnitude so that the value of the true gradient at the height h will be that due to the negative surface-charge of the Earth, acting alone. Thus the effect of a positive space-charge layer below the collector is to cause the gradient as determined by this method to exceed the point-gradient at the collector by 2π times the space-charge in a column of unit cross-section of that layer, and similarly to be less than the gradient at the Earth's surface by the same amount.

Case 2 –If the space-charge is negative and homogeneous, of density $-\rho$ throughout the region below the collector and σ_0 is negative, then equation (2) becomes

$$V/h = 4\pi\ (\sigma_0 - \rho h/2) \qquad (2b)$$

Thus the effect of a negative space-charge layer below the collector is to cause the apparent gradient as determined by this method to be less than the actual gradient at the collector by 2π times the space-charge in a column of unit cross-section of that layer, and similarly to exceed the gradient at the Earth's surface by the same amount. It must, however, be borne in mind that if this negative space-charge is caused by a separation of positive and negative charges in the air (such as is hypothesized by Simpson[1]), the positive charges being carried upward and the negative remaining below, the total quantity of space-charge of each sign being equal in the air above the place where the potential difference is measured, the above conditions for a negative potential-difference cannot be consummated. The σ_0-term in this case, including as it does the surface-charge induced by positive space-charge in the upper layers of air, above the collector, will necessarily be greater than half the negative space-charge in a column of unit cross-section of that layer.

(2) *Consideration of a non-homogeneous space-charge layer of infinite horizontal extent* If the space-charge density varies with height so that $f(h_0)>f(h_1)$ . . . etc., for increasing values of h and the value of $F(h)$, the total space-charge in a unit column of height h is expressible by a mean value ρh; that is, the total space-charge below the collector will be the same as in the two preceding cases but its density will decrease with height, and σ_0 is negative then the relative values of the terms change. Writing equation (2) and the equation from which (2*a*) was derived, for positive values of the space-charge

$$V/h=4\pi\ [\sigma_0+F(h)-G(h)/h]$$
$$V/h=4\pi\ [\sigma_0+\rho h-\rho h/2]$$

it may be seen that V/h in this case will be greater than, equal to, or less than V/h for case 1 accordingly as the term $G(h)/h$ is less than, equal to, or greater than the term $\rho h/2$, $F(h)$ being equal to ρh. It is evident that $\int f(h)dh$ is greater than the product ρh for all values of h less than the limiting value. Therefore, by the theorem of mean value

$$\int_0^h F(h)\,dh > \int^h \rho h\,dh=\rho h^2/2$$

Hence the value of V/h in this case is less than the value of V/h in case 1. It is also obvious that as the entire space-charge may be concentrated in a thin layer on the ground, the limiting value of $G(h)/h$ is ρh, so that the minimal value which V/h can assume in this case is $4\pi\sigma_0$, the actual value of the gradient at the collector.

Thus it is shown that for equal values of space-charge below the collector, lesser potential differences will be observed if the space-charge is more dense near the ground.

Similarly it may be shown that if the space-charge density increases with height, greater potential differences will be observed than in the case of homogeneous distribution, the maximal and minimal values of V/h being $4\pi\ (\sigma_0+\rho h)$ and $4\pi\ (\sigma_0+\rho h/2)$ respectively. Analogous conditions obtain if the space-charge is negative and non-homogeneous.

From the foregoing it may be seen that any attempt to measure the space-charge density by the difference in the so-called gradient as determined by collectors situated at different elevations by the equation

$$\triangle(V/h)/\triangle h=-4\pi\rho$$

is essentially erroneous. If the values of $\triangle(V/h)$ are given by $(V/h-V'/h')$ etc., then the value of the space-charge density, assuming homogeneity is given by $\rho=(V/h-V'/h')/2\pi\ (h'-h)$.

(3) *Application to the determination of the reduction-factor of a potential-gradient recorder* These effects of space-charge are particularly significant when reduction-factor determinations are considered. If it is desired to obtain the reduction-factor of a potential-gradient recorder, that is, the ratio of the potential difference between the Earth and a point one meter above the Earth in a region where the equipotentials are horizontal to the potential difference given by the recorder, the common procedure is to set up a standardizing collector one meter above the ground in a suitable place and compare values of the potential difference as measured by this collector with those values simultaneously measured by the recording collector. Naturally, the more similar the dimensions

of the recording and standardizing collectors and the geometric configurations of the regions around each, the less will be the discrepancies among individual determinations of the reduction factor.

Collector-systems used by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in connection with potential-gradient recorders are of a design in which errors of this nature are practically negligible. These collectors are mounted on the sides of buildings where the field-intensity is about 1.7 times that of an open plain. The distance from the active portion of the collector to the nearest earthed object is about 60 cm. making the reduction-factor about 1.0. It is interesting to compare this type of collector with a type such as was used on the *Maud*[2] Expedition. This collector was mounted in a field about 0.9 times as intense as an open plain. The distance from the active portion of the collector to the ground was 180 cm, making the reduction-factor about 0.6. Exact investigation of the effect of space-charge on determinations of the reduction-factor of each of these collectors requires a development which will not be considered in this paper, although a qualitative idea of the effect may be derived from the following simplified case.

Suppose a potential-gradient recorder to be operating with the active agent of the collector placed two meters above the ground in a region where the electric field is undistorted. Reduction-factor determinations are made by the method outlined above. If the value of σ_0, that is, the surface-charge of the Earth not induced by space-charge below the two-meter level is 2.7×10^{-4} esu per cm^2, Table 1 shows the potential difference given by the recorder, the potential difference given by the standardizing instrument, and the reduction-factor as determined by this method for various densities and distributions of space-charge.

Table 1—*Computed values of potential differences at recording and standardizing collectors for various densities of positive space-charge layer of considerable horizontal extent two meters thick and adjacent to the Earth*

Space-charge present at	Space-charge density	Recording collector	Standardizing collector	Reduction-factor
	esu/m^3	*volts*	*volts*	
Recording and standardizing collectors	0.0	204	102	0.50
	0.2	218	113	0.52
	0.4	234	124	0.53
	0.6	249	136	0.55
At recording collector only	0.2	218	102	0.47
	0.4	234	102	0.44
	0.6	249	102	0.41
At standardizing collector only	0.2	204	113	0.55
	0.4	204	124	0.61
	0.6	204	136	0.67

The space-charge values given in Table 1 are by no means unusual—in fact, they are less in range and magnitude than the mean hourly

[2]Res. Dep. Terr. Mag., 1918-1926, 6, 431 (1927).

values of space-charge observed at Washington by Gish and Sherman in November 1928.[3] The values in the Table show how single determinations of the reduction-factor for any one recorder may exhibit much scattering even though the space-charge may be the same at both recording and standardizing collectors. Not only is it essential that space-charge conditions remain constant at all times in order that a number of reduction-factor determinations may agree among themselves, but unless space-charge conditions do remain constant the reduction-factor itself is subject to variation. By a similar computation it may be shown that, space-charge conditions remaining constant, reduction-factor determinations will yield different results if made at times when the potential gradient has different values.

Since space-charge does vary over wide limits it is necessary to bear in mind its effect upon potential-gradient measurements when deducing therefrom any conclusions as to the variation of potential gradient as a general phenomenon, particularly if such a variation exhibits close similarities to the variation of some other local condition. Of course a phenomenon like the diurnal variation of potential gradient as a function of universal time is essentially not due to effects of this type.

(4) *Consideration of the surface-charge induced by a space-charge layer of limited horizontal extent*—Up to the present the space-charge layer has been assumed to be of infinite horizontal extent. However, if there is to be a difference of space-charge at the recording and at the standardizing stations it follows that the layer must be quite definitely of finite extent. Unless errors introduced by the preceding assumption are negligible the method of treatment is unwarranted. The effect of limiting the horizontal extent of the space-charge layer is two-fold: First, it will reduce the value of the induced surface-charge density from what it would be for a layer of infinite extent; and second, the effect of the space-charge itself will be less than if it were of infinite extent. In this case the field-lines will be warped so that a special treatment of the problem is necessary. Although the problem is by no means explained by considering the magnitude of the induced charge alone, this aspect is so interesting *per se* that it will be considered first. Later combined effects of space-charge and the induced surface-charge will be developed for certain special configurations of the space-charge.

Consider a cylindrical column of space-charge (Fig. 1) adjacent to the Earth, of height h, radius r, and density ρ. The force at P due to an element of the volume $r\,\mathrm{d}\phi\,\mathrm{d}r\,\mathrm{d}h$ is

$$-\rho r\,\mathrm{d}\phi\,\mathrm{d}r\,\mathrm{d}h/(r^2+h^2)$$

and the vertical force downward is

$$\rho h r\,\mathrm{d}\phi\,\mathrm{d}r\,\mathrm{d}h/(r^2+h^2)^{3/2}$$

But as the point P is at the surface of a plane conductor of infinite thickness and extent, there will be a second force acting of the same magnitude and direction which may be considered as due to the image of the ele-

[3] Carnegie Inst., Year Book No. 28, 261-262 (1929).

ment of the space-charge considered. Therefore, integrating for the entire cylinder we have

$$2\rho\int_0^h\int_0\int_0^{2\pi} h\,r\,\mathrm{d}h\,\mathrm{d}r\,\mathrm{d}\phi/(h^2+r^2)^{3/2}=4\pi\rho\ \left(\sqrt{h^2+r^2}-r-h\right)$$

and since $\mathrm{d}V/\mathrm{d}h=-4\pi\ \sigma_t$

we have

$$\sigma_t=-\rho\ \left(h+r-\sqrt{h^2+r^2}\right)\ \text{or}\ -\rho h\ \left(1+K-\sqrt{K^2+1}\right)$$

in which K is the ratio of the horizontal extent of the space-charge, measured from P, to the height of the cylinder.

Obviously, as K becomes large so that $(K-\sqrt{K^2+1})$ is negligible the value of σ_t approaches $-\rho h$ as a limit. The values of σ_t in terms of ρh

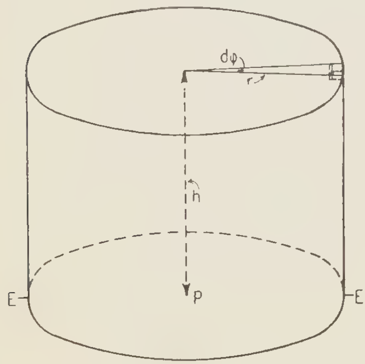

Fig 1

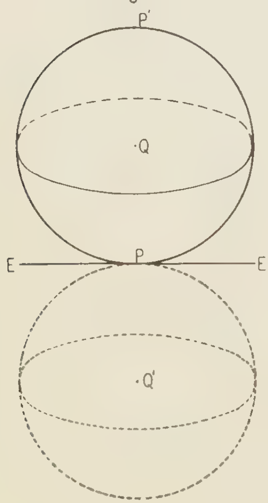

Fig. 2

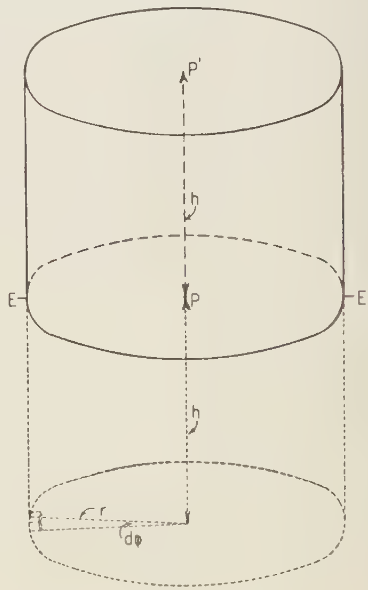

Fig 3

Fig. 1—Space-charge in cylindrical volume at Earth's surface inducing change at P

Fig. 2—Space-charge in spherical volume tangent to Earth at P and image within Earth collector at P'

Fig. 3—Space-charge in cylindrical volume at Earth's surface and image within Earth collector at P'

as it approaches its limiting value for increasing values of K are -0.586, -0.764, -0.901, -0.950, and -0.995 for K equal 1, 2, 5, 10, and 100, respectively.

(5) *Consideration of the potential difference due to certain geometrical configurations of space-charge*—As stated before, the surface-charge density due to a space-charge layer of limited horizontal extent does not give a complete picture of the resulting electrical field. As the induction under the center of a finite volume of space-charge is less than the induction for an infinite volume, so also the effect of a finite volume of space-charge upon the measurements of potential will be less than for an an infinite volume. To illustrate this, two possible configurations of the space-charge distribution will be investigated although an endless variety of forms may be conceived. The first of these is a spherical volume of space-charge tangent to the Earth's surface with the collector situated at the opposite end of the diameter of the sphere through the point of tangency. The second is a right cylinder one face of which coincides with a portion of the Earth's surface, the collector being situated at the intersection of the axis of the cylinder with its upper face. In both of these cases the dimensions of the volumes of space-charge will be small as compared to the Earth's diameter so that the previous assumption, namely, that the Earth is an infinitely thick conductor with a plane face of infinite extent, remains valid.

Considering first the sphere, the method of images may be applied advantageously. The Earth's surface EE (Fig. 2) is an equipotential surface with respect to which it is wished to find the potential at P'. The total charge in the spherical volume is $(4/3)\ \pi r^3\rho$ in which r is the radius of the sphere. This charge may be considered as concentrated at Q. The image of the charge whose magnitude is $-(4/3)\ \pi\ r^3\rho$ may be considered as concentrated at Q'. Since P and P' are equidistant from Q, the difference of potential between those two points due to the space-charge alone is zero. It is thus necessary to consider only the potential difference due to the image of the charge. The potential difference is then

$$-(4/9)\ \pi\ r^2\rho+(4/3)\ \pi\ r^2\rho=(8/9)\ \pi\ r^2\rho$$

and if $h=2r$

$$V/h=(2/9)\ \pi\ \rho h$$

Thus the effect of a positive space-charge of the form considered is to increase the value of V/h by $(2/9)\pi$ times the total space-charge in a column of unit cross-section beneath the collector.

In the case of a cylindrical volume of space-charge a condition in part similar is encountered; namely, that the effect of the space-charge alone is zero and that the potential difference between the collector and the Earth may be derived by considering the image of the charge only. The potential at any point along the axis due to a volume element of the image is

$$-\rho\, r\, \mathrm{d}\phi\, \mathrm{d}r\, \mathrm{d}h/\sqrt{h^2+r^2}$$

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so that the potential difference between P and P' is

$$-\rho\left[\int_h^h\int_0^r\int_0^{2\pi} r\, \mathrm{d}h\, \mathrm{d}r\, \mathrm{d}\phi \,/\sqrt{h^2+r^2} - \int_0^h\int_0^r\int_0^{2\pi} r\, \mathrm{d}h\, \mathrm{d}r\, \mathrm{d}\phi \,/\sqrt{h^2+r^2}\right]$$

$$=2\pi\rho h^2\,[1+\sqrt{K^2+1}-\sqrt{K^2+4}+(1/2)\,K^2\log\,(1+\sqrt{K^2+1})^2/$$

$$K\,(2+\sqrt{K^2+4})]$$

in which K is the ratio of the horizontal extent of the space-charge measured from P to the height of the layer or

$$V/h=2\pi\rho h\ \ [1+\sqrt{K^2+1}-\sqrt{K^2+4}+(1/2)\,K^2\log\,(1+\sqrt{K^2+1})^2/$$

$$K\,(2+\sqrt{K^2+4})]$$

From the effect upon V/h of cylindrical volumes of the type described for various values of K it may be seen that errors introduced by the assumption that such a configuration of space-charge is of infinite horizontal extent are quite negligible if the horizontal extent is several times the height. Thus the increases of V/h due to space-charge in terms of $\pi\rho h$ are 0.674, 1,260, 1.796, 1.924, 1.992, and 2.000 for values of K equal 1, 2, 5, 10, 100, and ∞, respectively.

SUMMARY

The investigations presented show that no configuration of positive space-charge will produce negative values of V/h, the commonly accepted measure of the gradient of the Earth's electric field. If the space-charge in the atmosphere below the collector is positive V/h may be negative only if the surface-charge of the Earth is positive at the place where the gradient is measured. It is likewise apparent that, under certain conditions, negative values of V/h may result from negative space-charge in the atmosphere below the collector although the true gradient at the collector may be positive. Variations in the value of V/h as determined in this manner must be considered with particular caution in deducing therefrom any generalized notions as to the variations of the Earth's electric field as the variations may be due to changes taking place only in the first two or three meters of the Earth's atmosphere while phenomena which obtain a few meters above may be quite different.

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NOTES ON THE JULY 1932 MEETING OF THE COMMITTEE ON SYMBOLS, UNITS, AND NOMENCLATURE OF THE INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS, TO DISCUSS MAGNETIC UNITS

By Arthur E. Kennelly*

Purpose and Scope—The purpose of this communication is to lay before readers of Terrestrial Magnetism and Atmospheric Electricity an unofficial historical outline of the international actions on C. G. S. magnetic units during the last five years, up to and including those of the Committee on Symbols, Units, and Nomenclature (S. U. N. Committee) at its recent meeting in Paris, July 9, 1932,—together with certain deductions that seem to follow therefrom. For more precise and authentic information, reference may be made to the official minutes of these various meetings, which are too lengthy to be included here.

Brief historical outline of C. G. S. magnetic units up to 1925—Gauss showed in 1833 how to reduce terrestrial magnetic observations with suspended magnets to absolute measure, that is, to units of length, mass, and time. Weber, cooperating with him, extended the scope of these researches in 1840 and 1851. They employed the millimeter-milligram-second (M. M. S.) system. Magnetic observatories began to keep records in these units about 1845. The rapid growth of electric telegraphy in 1860, created a demand among telegraph engineers for electrical units. At a meeting of the British Association for the Advancement of Science (B. A.) in 1861, a paper was presented by the telegraph engineers Clark and Bright, pointing out the need for scientific measurements and units in that field. The first B. A. committee was then appointed to report upon "Standards of electrical resistance." It issued several annual reports and continued until 1867. It recommended the adoption of units in the meter-gram-second (M. G. S.) absolute system. It issued standard B. A. resistance-coils, and standard condensers in that system, as *ohms* and *microfarads*, respectively. It proposed the *volt*, approximately at its present unit magnitude; but did not reach the stage of issuing standards of electromotive force.

The second B. A. committee was appointed for "The selection and nomenclature of dynamical and electrical units." It presented its first report in 1873. It adopted the B. A. standard *ohm*, *volt*, and *farad* of the first B. A. committee, but changed its basic system from the M. G. S. to the C. G. S. (centimeter, gram, and second). It extended the scope of the latter system to include a number of physical sciences.

The *volt*, *ohm*, and *farad*, as decimal derivatives of the C. G. S. system of magnetic units, with their corresponding B. A. standards, continued to find favor and extended use. They first received international adoption at the Paris Congress of 1881. That Congress adopted the C. G. S. system, with the *ohm* and *volt* as its decimal derivatives. The *ampere*, *coulomb*, and *farad* were adopted from unitary relations with the *ohm* and *volt*. An international commission was charged with the determination of the standard mercury-column resistance embodying the *ohm*. That commission reported in 1884.

The second International Electrical Congress at Paris, in 1889, added to the series of practical units three more, namely, the *joule*, *watt*, and *quadrant* (subsequently renamed the *henry*), as decimal derivatives of the corresponding C. G. S. units.

In 1891, a Committee on "Units and standards" (U. & S.) of the American Institute of Electrical Engineers (A. I. E. E.), recommended that at the next international electrical congress (Chicago, 1893), four

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magnetic units should be adopted in the practical series, and given names: For magnetomotive force, 10^{-1} C. G. S. unit or $1/4\pi$ ampere-turn; for magnetic flux, 10^8 C. G. S. unit; for flux-density, 10^8 C. G. S. unit of flux per square centimeter; and for reluctance 10^{-9} C. G. S. unit. No names were suggested in the report, which was accepted, printed, and brought to the attention of the Chicago Congress.

At the International Electrical Congress of Chicago in 1893, the question of magnitudes and names in the volt-ampere-ohm series, to magnetic units, was (1—see bibliography at end of article) discussed in the Chamber of Delegates. The Congress recommended that for magnetic units, the C. G. S. system should be used, and that for the present, no names should be given to them.

In view of this recorded decision of the Chicago Congress, the U. & S. Committee recommended to the A. I. E. E. in November 1893, the provisional adoption of names for four C. G. S. magnetic units: The *gilbert* for magnetomotive force $\mathfrak{F}$, the *weber* for flux Φ, the *oersted* for reluctance $\mathfrak{R}$, and the *gauss* for flux density B. This recommendation was adopted, and the American delegation to the next following Congress of 1900, was instructed to favor their adoption, and also to recommend international consideration of rationalising the C. G. S. magnetic units (making the unit of mmf. equal to the *abampere-turn* instead of the 4πth part of an *abampere-turn*).

At the Paris Congress of 1900, it was decided not to consider rationalising the C. G. S. magnetic units, and only to give names to two of them, namely, the *maxwell* for flux Φ, and the *gauss* for magnetic field intensity H. There was some misunderstanding in the meeting and some of the delegates understood that the *gauss* was adopted (3) for flux-density B, until the Minutes (2) of the meeting were published.

The International Electrical Congress of 1904, next following, in St. Louis, itself took no action in regard to electric or magnetic units, but recommended that in future, international actions in electrical matters should be divided between two international bodies: One, later called "The International Conference on Electrical Units," consisting of government delegates, which dealt especially with the electrical national standards maintained by legislative authority, and the other, "The International Electrotechnical Commission" (I. E. C.), a permanent body, organised in 1906 by Col. R. E. Crompton, and with its General Secretariat in London. The I. E. C. dealt especially with the standardisation of electrical machinery; but one of its advisory committees—No. 1 on "Nomenclature"—has for a long period discussed units, standards, symbols, and definitions. The I. E. C. also authorises the holding of international electrical congresses.

Since 1900, no international congress has attempted to formulate decisions in regard to electric or magnetic units; but ambiguity and confusion have steadily increased in the magnetic literature of all countries, over the meanings, symbols, and formulas of certain magnitudes and their units, especially as regards the *gauss*. Some writers have used this name for the unit of magnetising force H, others for that of flux-density B; and still others for both H and B indiscriminately. Moreover, some text-books have maintained that H and B stand for physically identical quantities, under which assumption, of course, the *gauss* would be applicable to both. Other text-books have declared that in any magnetic circuit, H and B represent physically different quantities, in which case the name *gauss* might be applied to the unit of one, but not to that of the other. In no country's magnetic literature has this confusion been entirely absent. To those who held B and H to be identical, their ratio B/H, the permeability μ of a magnetic-circuit medium, or even μ_0 the permeability

of vacuum and free space, became a mere numeric or "dimensionless" quantity, while to those who held B and H to be essentially different, or to have different physical dimensions, μ and μ_0 were not mere numerics, but likewise had dimensions of some kind. From an engineering standpoint, the dimensions assigned to permeability may not be important; but from the standpoint of unitology, it is manifestly desirable that the definitions and meanings of these terms and symbols should be internationally standardised. It is generally admitted on both sides of this controversy -now more than thirty years old—that there are logical definitions in the text-books of leading authorities which will support either hypothesis. That is, there are certain authentic definitions under which B and H become identical quantities, with μ a mere number, and again other authentic text-books with definitions under which B and H are physically different, with μ a non-numeric.

I. E. C. actions at the meetings of Bellagio and Oslo—No international action was taken on this vexed question of the *gauss*, until 1927, when the I. E. C. at its eighteenth plenary meeting, in Bellagio, Italy, discussed certain proposals on magnetic units, and appointed an international subcommittee (5) representing seven countries, to consider and report upon the matter. This subcommittee was later enlarged to represent twelve countries, as Section B of No. 1 Advisory Committee on Nomenclature, dealing with electric and magnetic magnitudes and units (E. M. M. U.)

The E. M. M. U. Committee worked for a year by correspondence, without success. There was so much difference of opinion and usage in the different countries, that no agreement on magnetic units was possible. The committee reported (7) in 1929, that the subject of magnetic units should be agitated in the various countries and should be placed on the agenda of the next I. E. C. meeting, to be held in Scandinavia in the following year.

The E. M. M. U. Committee, meeting in Scandinavia June-July 1930, decided that the first necessity for international agreement was to arrive at a convention as to whether permeability μ should be accepted as having real dimensions or not. After some discussion, it was unanimously agreed that for electrotechnical purposes, B and H should be taken as representing different quantities, and with their ratio μ as having dimensions. Accordingly, the *gauss* could only be accepted as applying to one of the pair. It was recommended to assign it to flux-density B, and in order to indicate that, in the opinion of the committee, the name *gauss* should not be applied to magnetising force H, the unit name *oersted* was selected for H. The *maxwell* of 1900 was then reaffirmed, and the *gilbert* recommended for the unit of magnetomotive force $\mathfrak{F}$ (mmf). These decisions, all either unanimous, or voted by a considerable majority of the representatives of ten countries, were reported to the plenary meeting of the I. E. C. at Oslo, in July 1930, and the report was unanimously adopted. Table 1 shows the units, unit names, and symbols recommended by the E. M. M. U. Committee.

TABLE 1—*Magnetic units in the classical C. G. S. magnetic system, internationally adopted by the Oslo I. E. C. meeting of 1930*

Recommended name	For C. G. S. magnetic unit of	Symbol
Maxwell	Magnetic flux or flux of magnetic induction	Φ
Gauss	Flux-density	B
Oersted	Magnetic field-strength, magnetic intensity, or magnetising force	H
Gilbert	Magnetomotive force	$\mathfrak{F}$

The committee also made recommendations in regard to other matters of unitology outside of the C. G. S. system, which need not here be considered. Reference may be made to the E. M. M. U. (8) Minutes, I. E. C. Document 77.

Action of the E. M. M. U. Committee in London 1931—In view of certain criticisms of the actions at Oslo that appeared after that meeting in the electrotechnical journals, it was decided to hold another meeting of the E. M. M. U. Committee at London, in September 1931, to review the recommendations already made.

In July 1931, the International Union of Pure and Applied Physics, (I. P. U.), at its meeting in Brussels, established (12) a Committee on Standards, Units, and Nomenclature (S. U. N.), under the chairmanship of Sir Richard Glazebrook, F.R.S. The S. U. N. Committee was invited and requested by the I. E. C. to aid in arriving at complete international agreement on magnetic units, after consulting the views of physicists in different countries. The S. U. N. Committee accepted the request. Three of its members attended the London meeting of the E. M. M. U. Committee, which was held in September 1931. It was unanimously voted at that meeting by representatives of eight I. E. C. national committees (two other countries not voting), to endorse the recommendations concerning C. G. S. magnetic units made at Oslo in the preceding year, and to leave those recommendations undisturbed (I. E. C. Document R. M. 97—see 13).

Actions of the S. U. N. Committee at Paris in 1932—The S. U. N. Committee met at Paris July 9, 1932, under the chairmanship of Sir Richard Glazebrook, and with Dr. E. Griffiths as Secretary. Eight countries were represented by nineteen persons in all. The Committee had already received and tabulated replies to a questionnaire (14) on the subject of electric and magnetic units, which it had issued in December 1931. Votes were taken at the meeting, not by countries but by representatives present, on eight propositions appearing on the agenda. So far as concerns C. G. S. magnetic units, here under consideration, the meeting adopted the following propositions, either unanimously, or by a considerable majority.

(*A*) The C. G. S. system of units is suitable for the physicist.

(*B*) The following Table 2 of magnetic units is acceptable:

TABLE 2—*C. G. S. units accepted by the S. U. N. meeting in Paris 1932*

Quantity designated	Symbol	Defining equation	Name
Flux	Φ	$d\Phi/dt = -E$	Maxwell
Induction or flux-density	B	$\int B\, dS = \Phi$	Gauss
Magnetomotive force round a circuit	F	$F = 4\pi NI$	Gilbert or oersted. cm.
Magnetising force or field-strength	H	$\int H.\cos\epsilon\, ds = F$	Oersted*
Permeability	μ	$\mu = B/H$	Permeability

*Messrs. Tuve and Hafstad of the Department of Terrestrial Magnetism have made very appropriately the following query: "The old unit for reluctance R was the oersted; now that this name is taken for H, what about reluctance?" Unfortunately, no substitute name for the C. G. S. unit of reluctance has been adopted, up to this date. The *oersted* has been taken away for H and nothing has been put in its place. At first, it was thought we should try to secure a new name for the C. G. S. unit of reluctance, and I think that it is generally agreed that such a name would be desirable. There is, however, still so much turbulence in the magnetic world over the main questions involved, that it seems better, for the present, to defer this question for a few years. There is good prospect of our having the main questions settled beyond dispute in Chicago in June 1933. Then, perhaps, the way will be open for dealing with reluctance.—*A. E. K.*

(C) That B and H are quantities of different nature.

(D) The factor $4\pi/10$ should be retained in the definition of magnetomotive force.

It will be seen that this S. U. N. table of C. G. S. units is in all essentials the same as the I. E. C. table of Oslo, and that the C. G. S. classical system, as adopted at Paris in 1881, should be retained unchanged and without rationalisation. The Oslo convention also endorsed that B and H should be taken as different physical quantities, with their ratio μ, the permeability, as a non-numeric.

The following proposition was also adopted:

(E) The system of magnetic units may be based on the following two methods as alternatives: (a) The force between two elementary magnetic poles (coulomb), and (b) The force between two elements of current (ampère). Dr. H. Abraham, the General Secretary of the I. P. U., was also requested by the Meeting to prepare for consideration by the Commission a preliminary report on the Fundamental Units.

Deductions that seem to follow from the I. E. C.-I. P. U. actions (1930-1932). The preceding historical outline of international actions on C. G. S. magnetic units having been carried up to and including July 1932, the following suggestions are made by the writer, as personal opinions.

From the foregoing historical outline, it will be seen that serious divergences in symbols, terms, and definitions had taken root in world magnetic literature since 1900, at least. In this confusion, no middle ground or compromise was possible. The I. E. C. and I. P. U. have, however, agreed upon a majority convention, through which agreement can be maintained: First by accepting the theory that B and H represent different physical quantities, with the *gauss* assigned to the former, and either the *gilbert per cm* or the *oersted* to the latter; second, that space-permeability μ_0 and likewise the absolute permeability μ of a magnetic medium have like dimensions; and third, that relative permeability μ/μ_0 of a magnetic medium is a mere numeric.

The literature of terrestrial magnetism encounters a special ambiguity to clear up, but at the same time finds a special loophole for escape from the past confusion. It has not only used the *gauss* as the unit of intensity of magnetic field H; but has also very generally used the name *gamma*, with the Greek symbol γ, for 10^{-5} *gauss*, by mutual agreement between the various magnetic observatories, as a convenient size of subdecimal in which to express terrestrial-magnetic observations. There has been no suggestion, however, of making any change in the meaning of the *gamma*, which remains applicable to the unit in the fifth decimal place of H. When it is necessary to specify the unit of H itself, according to the new convention, it should be written either as the C. G. S. unit of H, or as the *gilbert per cm*, or as the *oersted*.

Just as the fundamental C. G. S. magnetic formula for electromechanical force exerted by an electric field H_e on a point-charge e, is in dynes

$$f = H_e e \tag{1}$$

where H_e is the local gradient of electric potential in abvolts/cm—that is, in C. G. S. magnetic units of electric potential per cm, and e is in abcoulombs, or C. G. S. magnetic units of charge; so the fundamental formula for magnetomechanical force exerted by a magnetic field H on a point-pole m is in dynes

$$f = Hm \tag{2}$$

where H is the local gradient of magnetic potential in gilberts/cm and

m is the strength of the pole or the "quantity of magnetism" on its surface, one pole unit giving emergence to 4π maxwells of magnetic flux.

Air, at ordinary pressures and temperatures, being a feebly magnetisable gaseous medium, will have a permeability in C. G. S. magnetic units (abhenries/cm)

$$\mu = \mu_0 + 4\pi\kappa \tag{3}$$

where μ_0 is space-permeability, taken as unity in the C. G. S. magnetic system, and κ is the magnetic susceptibility of the medium. For standard atmospheric pressure, and 20° C, κ is given as 2.9×10^{-8}. Hence from (3), $\mu = 1.00000036$ or the flux-density B will not exceed the magnetising force H by more than about one part in three millions, a correction too small to be taken into account for the present degree of precision attainable in magnetic measurements. A field of $H = 1$ *oersted* or 1 *gilbert/cm*, or 100,000 *gammas*, would thus give rise to a flux-density B of 1.000000 *gauss* in the air. As a matter of convention, however, if the Earth's magnetic field were measured with a non-magnetic rotating coil or earth inductor, instead of with a freely suspended magnet, the quantity evaluated would be the flux-density B in the air, and not the magnetising force H.

If the coil has N equal parallel turns, each enclosing an active area of S cm², the maximum cyclic magnetic flux linked with the coil, in a plane perpendicular to its rotation axis, would be in *maxwells*

$$\Phi = S\,N\,B = S\,N\,\mu\,H \tag{4}$$

and with a uniform rotational angular velocity ω radians/sec, the maximum cyclic electromotive force E_m induced in the coil would be in *abvolts*

$$-E_m = \mathrm{d}\Phi/\mathrm{d}t = S\,N\,(\mathrm{d}B/\mathrm{d}t) = S\,N\,B\,\omega \tag{5}$$

The effective, or root-mean-square value E, of this alternating electromotive force is in *abvolts*

$$-E = -E_m/\sqrt{2} = S\,N\,B\,\omega/\sqrt{2} \tag{6}$$

and in *gauss*

$$B = -E\sqrt{2}/S\,N\,\omega \tag{7}$$

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REMARKS ON DR. KENNELLY'S NOTES

By J. Bartels

The readers of this Journal will be grateful to Dr. Kennelly for his clear summary. He stresses the usefulness of the international conventions for a uniform adoption of units—a usefulness which is rather independent from theoretical considerations about which there is no unanimity.

As to terrestrial magnetism it is a question whether the new conventions, especially the rather vague recognition of a physical dimension of the magnetic permeability, make a change in the usual practice necessary. I should like to support the unchanged use of the *gauss* (and of the γ as its 100000th part) as a unit even more strongly than Dr. Kennelly, for the following reasons: Practically all writers of text-books or papers on terrestrial magnetism neglected from the outset the susceptibility of air, a procedure fully justified by the negligible numerical difference between B and H, as Dr. Kennelly also points out. Thus, if we speak of the magnetic *field* of the Earth and of its intensity, we need not state definitely whether we mean the quantity which the convention calls magnetic field-strength H, or that which it calls flux-density B. (Furthermore, it is usual in terrestrial magnetism—and sanctioned by the International Meteorological Conference at Paris in 1896—to reserve the letter H for horizontal force. We therefore may as well talk of the total force or total intensity of the north component, etc., and express them in the unit gauss, as heretofore. A physicist adhering to the conventions is at liberty to take the values as expressing "flux-density".) As Dr. Kennelly states, with the electric magnetometers —for instance, the Schuster-Smith magnetometer—measurements are in fact made in the unit gauss as defined by the new international conventions.

As characteristic of the (justified) promiscuous use of H and B by workers in terrestrial magnetism, I translate a short passage by Adolf

Schmidt (Enzyklopädie d. mathem. Wissenschaften **6**, 1, *B*, p. 382, Leipzig, 1918): "Starting from the rather strong paramagnetism of oxygen, which he had discovered, and from its noticeable change with temperature, Faraday attempts to attribute the diurnal (magnetic) variation to a deformation of the lines of force of the Earth's field, connected with the heating and cooling of the atmosphere. Such an effect exists, of course, but it is far too small to be noticeable." This seems to indicate the conception of the "field" as flux-density. This point, however, has never been stressed because, until quite recently, in the German physical literature, H and B have been regarded as having the same dimensions, and μ has been regarded as a pure number—practically unity in air.

There is also an instrumental reason why it is inopportune to stress the difference between B and H in terrestrial-magnetic measurements: The "non-magnetic" materials, such as copper, marble, and wood, of which magnetic instruments consist, have all a (numerically) higher susceptibility than air; nevertheless it is neglected, and with good reason. Further, it is not at all clear (though unimportant), what the usual methods of measuring horizontal intensity would yield numerically in an evacuated room of a given shape, provided they could be used with sufficient accuracy. Finally, taking the conventions strictly, we ought to "reduce" the data from Huancayo, for instance, for the lower pressure and susceptibility of the air there, if we really wished to express the field in oersteds.

In short, there is no important reason why we should discontinue the established practice of talking of terrestrial-magnetic forces, for instance, the north component X, as expressed in gauss. Only in such cases where the susceptibility is high enough, so that the permeability deviates appreciably (by more than one-thousandth of one per cent) from the value in vacuum, the discrimination between flux-density B and field-strength H is essential. Such cases will occur, so far as terrestrial magnetism is concerned, mainly in instrumental questions, or in the interpretation of rock-magnetism, but will hardly enter into routine observatory or field work.

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[Note—With reference to Dr. Kennelly's article it is to be particularly noted that the distinctions he indicates between the quantities B and H must be taken account of in certain experimental researches in terrestrial magnetism, for example, on rocks. So far as general measurements of the Earth's field are concerned, and as Dr. Kennelly remarks, the distinction is of no practical consequence because the error arising in the usual practice followed in terrestrial magnetism is much within the highest attainable accuracy, using equipment of best present design. Dr. Kennelly's article makes concise record of the historical development of magnetic units and their relation to terrestrial-magnetic research. Under the circumstances so clearly enumerated by him and by Dr. Bartels the interests and viewpoint of the magnetician need involve no prolonged discussion or unitological controversy.—*Ed.*]

SUMMARY OF THE YEAR'S WORK, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON[1]

By J. A. Fleming

The death on April 12, 1932, of Louis Agricola Bauer, Director from 1904 and Director Emeritus from 1930 of the Department, removed from science an internationally recognized authority on geophysics. Largely through his enthusiasm and organizing ability, based on his earlier work in the magnetic survey of the United States Government, the systematic magnetic survey of the whole Earth, sponsored by the Carnegie Institution of Washington upon his initiative, was accomplished. This survey established the empirical basis of required accuracy for theoretical discussions of the origin and behavior of the Earth's magnetic field. Bauer was among those foremost in the discussion of terrestrial magnetism and of related geophysical problems, as is evidenced by his many scientific contributions. No small part of the international coordination of research in geophysics during the past forty years may be attributed to Bauer's devoted efforts. His was an increasingly important directive influence in the progress of terrestrial magnetism throughout the period of his active labors.

As in the preceding year, the year July 1, 1931, to June 30, 1932, was given over largely to the statistical investigations of the accumulated observational material and to the development of the possible laboratory attack on problems in terrestrial magnetism and electricty.

The discussion by Bartels of magnetic correlations with solar conditions utilizing all available data was completed. It is concluded from this discussion that there must exist in the Sun's surface certain restricted areas (M-regions), the lifetime of which is limited (up to a year), though generally longer than that of sunspots. They cause terrestrial-magnetic disturbances, very likely by emitting well-defined corpuscular streams. These solar regions, as individuals, escape the usual astrophysical means of observation (visual, photographic, and spectrohelioscopic); they can as yet only be traced in terrestrial-magnetic activity. Terrestrial-magnetic records have therefore obtained a purely astrophysical interest, beyond their well-known geophysical aspect, namely, the indication of the times when the Earth is actually under the influence of solar streams.

The investigation on the diurnal magnetic variation on selected quiet days was continued. The large material derived from harmonic analyses is ready for discussion, which will supplement, from a different viewpoint, the research into the variability of solar influences as indicated by magnetic activity.

Much attention was given the characteristic features of terrestrial-magnetic research, which are common to other branches of geophysical research, in comparison with those of laboratory physics. While the impossibility of keeping the relevant conditions of observation constant leads naturally to the use of statistical methods in geophysics, the policy of the Department, adopted over fifteen years ago, of effecting laboratory approach to its problems finds increasing justification in the rapid development of physics and astrophysics.

During this report-year efforts have been spent chiefly on the following items: (1) Tests of the inexpensive Van de Graaff electrostatic

[1] Extracted from the annual report in Year Book No. 31 of the Carnegie Institution of Washington for the year July 1, 1931 to June 30, 1932, to which reference may be made for more detailed account of field, observatory, instrumental, and laboratory work, and of publications.

generator in air as a source of high voltages for this type of work, including its use for first tests of steady direct-current potentials of the order of one million volts on cascade-type vacuum-tubes, and the construction and test of a 2000-kilovolt generator, which is ready for use as soon as laboratory-space is available for its erection. (2) Attempts to make such observations as have appeared possible using the spark-excited Tesla coil without an unreasonable expenditure of effort and funds attempting to use this rather poorly adapted voltage-source, especially with a much simpler and more effective equipment in process of construction and test here in the same laboratory at the same time. (3) The construction of instruments and development of techniques for the observation and measurement of atomic and nuclear phenomena using these high-energy rays, including (4) the application of the older technique using radioactive sources to certain specific problems of outstanding importance for which unusual facilities have been purposely acquired, in particular a very large amount of radium-*D* in solution, for preparing strong polonium-sources.

Using the Tesla coil and a "flashing" tube in connection with a Wilson cloud-chamber, first observations were made of the range in air of 1100-kilovolt protons. A systematic search for disintegration-phenomena was undertaken, but the technical limitations of the Tesla-coil equipment in these experiments showed that they might better be postponed until the Van de Graaff generator was installed. Meanwhile, steady progress was made on the program of developing instrumental techniques for new observations and measurements of basic importance using the high-voltage technique.

G. Breit of the faculty of the New York University and research associate of the Institution continued studies of the hyperfine structure of spectral lines due in part to the different position of spectral lines due to different isotopes of the same element. The displacements observed are much too large to be explained as the ordinary effect of the mass predicted by Bohr. He is investigating the possibility of explaining the shifts in terms of the size of the nucleus. It is found that the observed shifts are smaller than would be expected. Apparent contradiction of the arc- and spark-spectra of *Tl* has been explained by taking into account perturbations present between terms of the *Tl* spark-spectrum. *Hg* arc- and spark-spectra similarly fit in. The arc-spectrum of *Pb* is apparently more difficult to explain. However, a possibility due to changes in screening has been found. Also the order of magnitude of the expected shifts has been decreased by suitable modifications. The general conclusion is that isotope-shifts may be explained as due to changes in nuclear dimensions; the nuclear radius is supposed to be approximately proportional to the cube-root of the atomic weight; the distribution of positive charge within the nucleus is roughly uniform. The above theory is still tentative and more experimental data are needed for a satisfactory test.

Thus the deliberate attempt to provide a new means of attack on some of the most basic problems in magnetism and physics, by the development of artificial (high-voltage) sources of high-energy particles and radiations, undertaken by the Department in 1926, has been finally carried to a point where the technical difficulties have been overcome and its development as a research-tool has been largely completed. The

next stage, that of its effective application to specific problems, is now under way.

For the observational or statistical approach assurance of additional data much needed in the polar regions for the extension of the Gaussian spherical harmonic analyses of the Earth's magnetic field was given by the definite provisions made by numerous governments and private organizations to participate in the International Polar Year program of 1932-33. The efforts of the Department have helped the realization of this program: (1) In presenting the subject and in securing favorable Congressional action for participation of the United States in the full geophysical program during the Polar Year at a proposed College-Fairbanks station in Alaska; (2) in expanding the program at the Watheroo and Huancayo observatories; (3) in effecting arrangements for special magnetic and auroral observations at Point Barrow, Alaska; (4) in enlisting the interest of the American Telephone and Telegraph Company which is establishing earth-current stations at four places in New York, Maine, Illinois and Arizona; (5) in making earth-current equipment available for the Canadian station at Chesterfield Inlet, besides furloughing a member of the staff of the Department, upon the request of the Meteorological Service of Canada, to take charge; (6) in providing two observers and much equipment for the work to be done at the College-Fairbanks station; and (7) in loaning a magnetometer-inductor for use at the Cape Town station.

The assurance of participation in Alaska resulted in considerable cooperative activity with the Department of various governmental and other agencies which otherwise probably would not have been possible. Those interested include the Department of State, the Department of Commerce through the Coast and Geodetic Survey and the Bureau of Standards, the Navy Department through the Naval Research Laboratory, the War Department through the Signal Corps, the Department of Agriculture through its Weather Bureau, the Carnegie Institution of Washington through our Department, the Alaska Agricultural College and School of Mines, and the American Telephone and Telegraph Company, as well as several individual contributions for special purposes. The chief United States station thus established is that designated as the College-Fairbanks station, the terrestrial-magnetic, atmospheric-electric, earth-current, and auroral records and observations to be done at College and those in radio telegraphy and meteorology at Fairbanks, about 5.5 kilometers east-southeast of College. With the cooperation of the International Polar Year Commission and the United States Weather Bureau, the Department has arranged also for continuous magnetic registrations and for auroral and meteorological observations at Point Barrow, Alaska.

Copies of the polar values in our world quadrangle compilations of magnetic data, as requested by the International Polar Year Commission in its Leningrad 1930 meeting, were communicated to the Central Geophysical Observatory of Leningrad for publication in its catalogue of magnetic determinations in polar regions.

The results to come from the Polar-Year stations will be valuable also in investigations of the secular variation, the nature of which is gradually becoming better known as the accumulation of data steadily though slowly increases and is subjected to analysis. Investigations in the

light of this better knowledge have progressed to the point where it is generally recognized that it is desirable to approach the problem from a somewhat different standpoint from that hitherto adopted. Attempts to derive a satisfactory picture of the phenomenon by harmonic analysis have been disappointing, and the results of more abundant observations, with a more widely scattered distribution and covering a longer interval of time, are clearly indicating the reasons for this lack of earlier success. It now appears that superimposed upon a gradual change in the direction of the magnetic axis and the steady alteration in the magnetic moment of the Earth as a whole, which may be considered as the "true secular variation," there are other fluctuations of temporary character or having a shorter period, which should be evaluated and so far as possible eliminated before an analysis of the true secular variation can be profitably undertaken. It is well known, for example, that conditions associated with the cycle of solar activity indicated by the variations in the abundance of sunspots affect the annual mean value of the intensity-components derived from continuous values at observatories, and may also produce abnormal results when secular variation is obtained from single values at field-stations. Then there are other changes which have the appearance of being confined to restricted regions and which seem to run their course in a period of years; there is no present evidence that they are cyclical in character, or that the changes in one region are definitely connected with similar changes taking place in other remote regions. Obviously these changes should also be examined closely and their effect eliminated so far as possible before undertaking an analysis of the changes which presumably have their origin in causes affecting the entire Earth, and therefore constitute the true secular variation as assumed above.

Secular change for a given locality is most effectively determined from the continuous registrations obtained at that place by a standard magnetic observatory. The evaluation of the effect produced by the solar cycle can be fairly well determined for much of the Earth's surface from the present distribution of magnetic observatories, but that distribution is far from adequate to furnish the information necessary to outline the areas of regional activity. Only after there had been an accumulation of observations at widely scattered field stations, an accumulation to which this Department had contributed very substantially, was it possible to make any approximate picture of what has been taking place over the Earth as a whole, or to obtain a comprehensive idea of this extremely important aspect of the problem. While the apparent changes in the annual rates of secular change clearly indicate that the regional activity is far from constant, the time over which sufficiently accurate data have been gathered is much too short to state what the period may be through which the phenomenon runs its course. Efforts are being made in many countries to inaugurate or expand programs of periodic field-surveys from which the secular variation may be known in greater detail, and to all such efforts the Department has extended a sympathetic interest, and has given assistance where possible. The nature of the problem is such that substantial progress toward its solution demands that periodical observations be made at stations scattered over the whole surface of the Earth, and since in addition to the areas covered by the oceans there is much of the land-surface which is under jurisdictions wholly unable or at present indisposed to provide the means for work of this character,

there still remains an urgent demand for the continuance of the work which the Department has carried on since its organization. Because of this inherent characteristic of the problem it can not well be approached by any agency or organization under governmental control of a single country whose activities are necessarily restricted by national boundaries, nor by investigators working only in laboratories, no matter how well equipped. For this reason the organization of the Department is most fittingly adapted to carry on the work in the field and is regarded as a mobile agency for correlating and coordinating the otherwise detached operations by the different countries or within limited areas.

Realizing this responsibility, field work in a few areas where it seemed especially urgent has been undertaken, though the extent of the work has been necessairly restricted because of the demands of other commitments. The entire western hemisphere south of Canada and the United States comprises an area, over which the rates of secular change are in general very large; and, so far as can be determined by the limited material available, those rates diminish rapidly with distance from recognized centers and are far from constant from year to year. Magnetic observatories are too widely scattered to provide adequate information regarding these changes, and a reoccupation of selected field-stations was considered of immediate importance.

Among the earliest expeditions sent out by the Department, in its initial land magnetic survey, were those to the lands bordering on the Caribbean Sea. Two expeditions during the past year have retraced much of this same territory, which has also been visited in its various parts at intervals during the intervening years. One of these was along the South American coasts visiting the more accessible portions and comparing standards with magnetic observatories and the other through the more difficult interior portions of Venezuela, Brazil, and Peru. From preliminary studies of the secular variations derived from the results obtained on these expeditions, it is known that the annual changes in all the magnetic elements are exceptionally great in this general region, and furthermore that these rates are undergoing relatively rapid alterations. When lines of equal annual change for any element (the isoporic lines) are drawn, they therefore present complicated patterns. It is a matter of very great interest to discover if possible how these patterns may alter their forms or shift their positions in the course of years. If there were a sufficiently dense distribution of magnetic observatories from which continuous records of change were available, the problem would be much simplified. In the absence of such records, an attempt has been made to derive an answer to the question by a discussion of the results obtained in the field even though they are irregularly distributed over an area and throughout the interval. The results so far obtained appear to corroborate the conclusions provisionally stated that the isopors of declination forming an oval in eastern Brazil, the isopors of inclination forming a similar pattern in Ecuador, and the horizontal-intensity isopors surrounding the West Indies, are all contracting toward their respective centers at the present time. It is hoped that an extension of this investigation will show something of the character of these contractions and possibly of their interrelations.

An opportunity was presented by the availability of the services of Frederick C. Brown, a former observer in the Department, to assist Dr. C. T. Kwei, of the Department of Physics, Central China College,

to obtain desired experience in the technique of carrying out the program of field-observations, with the expectation that the Chinese national organizations may be able to undertake systematic magnetic observations within their own territories. The southern portion of the African continent is a region of exceptional secular changes, remote from any established observatory. It is, therefore, especially fortunate that the cooperation with the Department of Physics of the University of Cape Town could be continued. With the assistance of the Department, provision has been made for a permanent station there with the hope that a set of magnetograph-instruments may eventually be installed. Such instruments will be in operation during the Polar Year, the absolute instruments having been supplied by us. The work planned in cooperation with A. Walter, Director of the British East Africa Meteorological Service, was only partially completed because of adverse circumstances, and the arrangement has been continued. The plans for securing much desired magnetic data in the far north by means of observations on the ice at stations to be reached by the submarine *Nautilus* were not fully realized. A station was occupied in Spitzbergen, and one successful set of observations on moving ice was made.

Important results have been obtained experimentally in the study of the factors and laws determining ionic balance in the atmosphere and its relation to atmospheric pollution.

In atmospheric-electric studies of the Department during the past fifteen years, measurements of potential gradient and of conductivity received greatest attention. Emphasis has been placed on the character of the variations in these elements and upon securing some idea of their absolute values, rather than on procuring answers to the question of why the variations behave as they do. The small ions in the atmosphere are responsible for the conductivity and variations in their number bring about corresponding variations in conductivity. The change in the number of small ions is caused by variations either in their rate of production or in their rate of removal. Variations in the rate of removal of small ions from the atmosphere may result when they become attached to large ions and to condensation-nuclei and, therefore, studies were begun during the past year on the number and nature of these nuclei or particles.

From observations at the Department in Washington, it was found that, in general, the mobility of the large ion here is greater than that found by other investigators. One method of investigation showed 72 per cent of the condensation-nuclei to be uncharged, while another quite independent method showed 28 per cent to be charged, half positively and half negatively. Thus it appears all condensation-nuclei are capable of becoming large ions. Upon this basis the recombination-coefficient between small ions and large ions is five times the value of the coefficient for small ions and uncharged nuclei. The results justify for purposes of computing the rate of ionization the use of the equation now accepted as representing the equilibrium-condition between that rate of ionization and the rate of removal of small ions in the atmosphere. An appreciable diurnal variation in the rate of ionization would hardly be expected from consideration of the ways in which small ions may be produced in the atmosphere. However, the calculated rate of ionization showed a systematic and large diurnal variation. The first results were based upon eye-observations. These have now been supported by others based upon extensive and continuous registrations obtained with photo-

graphically recording apparatus. While this diurnal variation may be real, it must await confirmation by direct measurement before final acceptance. Several months of continuous recording of large ions were obtained before the end of the year. A preliminary analysis of the data has shown a change in the character of the diurnal variation with time, suggesting that other sources than merely products of combustion must be considered.

The study of terrestrial-magnetic variations and of the possible effects of such variations on radio waves and their relation to ionizing agents are sources of chief promise for information about the physical state of the outermost layers of our atmosphere and, thereby, about cosmical influences on the Earth. The compilation of lunar diurnal-variations at our two observatories, now well under way, must be expected to give data bearing upon the ionized regions of the upper atmosphere. Observational data on the variation in height of these ionized regions, following the development of the echo-method of determination initiated in this Department in 1925, are now being obtained regularly by the United States Bureau of Standards. Apparatus has been designed in cooperation with the Bureau of Standards and is being constructed in the instrument-shop to record these variations at Watheroo and Huancayo—such work at the latter Observatory is especially desired because of the unique conditions set up by present theories of the ionized regions and of auroral phenomena in the equatorial belt. Greenleaf W. Pickard, research associate, reported on continuation of the systematic recording of radio transmission at Tufts College, Massachusetts, and at Pasadena, California, under the direction of G. W. Kenrick and Howell C. Brown. Feeling that the question of a lunar period in radio transmission required further study, much time was devoted to harmonic analysis of all available reception-series in an attempt to determine the reality of this period. As the result of an analysis of ten years of Austin's day fields from European stations, six years of night fields from WBBM, five years of Pasadena night fields from San Francisco, and four years of the WCI records, it appears the case of the existence of a lunar period was somewhat strengthened, although the analysis has also shown that in general the amplitude is small.

Satisfactory experiments have been made with the automatic swing for the detection and measurements of centrifugal couples of dummy compasses subject to ship's rolling motion. The theory has been investigated and the comparison of theory with experiment in general is fair. There remains a discrepancy in the magnitude of the deviation which has yet to be accounted for probably by the differences in the conditions of the experiments and the assumptions made in the theory. The investigation, however, has proceeded far enough to begin experiments with various types of compasses. Experiments with the automatic swing are yielding valuable information on the probable behavior of compasses subject to ship's motion. They suggest the possibility of correcting for such effects, at least to some extent, the magnetic results already obtained by the Department at sea. The investigation also suggests that ship's compasses in general might be improved by a more careful distribution of mass in the compass-card according to definite specifications. This work has already suggested improvements for the Department's marine collimating-compass used for so many years on the *Carnegie*.

Various solutions to the problem of making magnetic observations at

sea in cooperation with expeditions that might employ vessels or dirigibles of ordinary construction have been and are still being considered. A reactor was designed for experimental work on an earth-inductor method of measuring magnetic intensity from a moving support and a preliminary design was prepared for a remote reading-instrument to determine magnetic dip and intensity at sea.

The magnetic, atmospheric-electric, earth-current, and meteorological programs at the Watheroo and Huancayo observatories, the atmospheric-electric program in the Deck-Observatory in Washington, and the cooperative work in atmospheric electricity with the Apia Observatory of the Department of Scientific and Industrial Research of New Zealand, and in atmospheric electricity and earth-currents at the Tucson Observatory of the United States Coast and Geodetic Survey, were maintained. Seismological and radio observatories were built at Huancayo, radio power-equipment and a vertical-component seismograph were installed, and two horizontal-component seismographs were shipped for installation. Spectrohelioscopes loaned by the Mount Wilson Observatory were installed at the Watheroo and Huancayo observatories.

Preliminary studies of earth-current data from the Watheroo, Huancayo, and Tucson observatories were made. Data were assembled from the Watheroo and Ebro observatories comparing the character of diurnal variation on disturbed with that on quiet days for a five-year period. The difference found was similar to that disclosed in similar comparisons of magnetic data, thus disclosing a further interesting relation between the variations in earth-currents and those in terrestrial magnetism. Another interesting relation was revealed in a comparison between the electric and magnetic variations on some abnormal quiet days. Further study was given to a possible explanation of the "anomalous" vertical earth-currents, which measurements in mountainous regions, in wells, and in mine-shafts are often interpreted as indicating. Measurements obtained in a dry well at the Huancayo Magnetic Observatory during June to August 1931, indicating apparently diurnal and shorter-period variations in the registrations of "vertical" earth-current, offer a difficulty. It was thought possible that, because of heterogeneity in the conductivity of the structure about the well, a component of the horizontal earth-currents may be registered between the surface and bottom of the well. However, these data would seem more consistent with the view that a large part of the indicated vertical-current variations is part of a non-potential system, similar to that indicated by magnetic line-integrals.

The reductions and compilations of the work in physical and chemical oceanography and in marine meteorology from observations made during the last cruise of the *Carnegie* were continued and the compilations and discussions were well advanced. Cooperating agencies also report good progress in the examination of bottom-samples and of biological samples.

The Department's policy of cooperating with other investigators and organizations interested in its geophysical researches was maintained. This was particularly the case, not only in endeavors to increase the magnetic secular-variation material so urgently required, but also in the field of atomic and nuclear physics.

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WERTE DER KUGELFUNKTIONEN UND DEREN ABLEITUNGEN FÜR DIE WICHTIGSTEN ERDMAGNETISCHEN OBSERVATORIEN*

Von G. Fanselau

Es liegt in der Natur geophysikalischer Probleme, dass man bei deren Behandlung häufig gezwungen ist, zu Reihendarstellungen zu greifen. Unter den hierbei hauptsächlich zur Verwendung gelangenden Funktionsreihen spielen die Kugelfunktionen wegen der entsprechenden Erdgestalt eine ausgezeichnete Rolle. Um nun die vielen Untersuchungen besonders erdmagnetischer Natur, zu deren Ausführung solche Funktionen gebraucht werden, zu erleichtern, sind in den folgenden Tabellen die Werte der Kugelfunktionen mitgeteilt für eine Anzahl der wichtigsten erdmagnetischen Observatorien.

Die in folgenden angewandte Bezeichnungsweise schliesst sich vollständig an die von Ad. Schmidt in seinen letzten Arbeiten über Kugelfunktionen[1] gebrauchte an. Danach sind im wesentlichen[2] drei verschiedene Arten von Kugelfunktionen zu unterscheiden, deren eine aus der anderen lediglich durch Multiplikation mit einem konstanten Faktor hervorgeht. Mit dieser Bezeichnungsweise, deren allgemeinste Einführung zur Vermeidung von Missverständnissen und Unklarheiten sehr erwünscht und empfehlenswert ist, bedeutet: (1) $P^{n,m}$ eine zugeordnete Funktion Laplacescher Art (von Gauss benutzt); (2) $P_{n,m}$ eine zugeordnete Funktion Neumannscher Art (in der theoretischen Physik häufig verwandt); (3) P_n^m eine zugeordnete Funktion Schmidtscher Art (quasinormiert). Dabei ist $P^{n,m}$ definiert als

$$(1) \qquad P^{n,m} = s^m \Big[c^{n-m} - \frac{(n-m)\,(n-m-1)}{2(2n-1)} c^{n-m-2} + \frac{(n-m)\,(n-m-1)\,(n-m-2)\,(n-m-3)}{2\times 4\,(2n-1)\,(2n-3)} c^{n-m-4} - \ldots \Big]$$

$$= s^m c^{n-m} \sum_{i=0}^{\frac{n-m}{2}} (-1)^i c^{-2i} \frac{\binom{n-m}{2i}}{\left(\binom{2n-1}{2i-1}\right)}$$

mit $s=\sin\theta$, $c=\cos\theta$ in einem Kugelkoordinatensystem (θ = Polabstand, ϕ = Länge)

$$x_0 = r\cos\theta;\ x_1 = r\sin\theta\cos\phi;\ x_2 = r\sin\theta\sin\phi$$

$$\left(\binom{2n-1}{2i-1}\right) \text{ bedeutet } \frac{(2n-1)\,(2n-3)\,(2n-5)\ldots(2n-2i+1)}{1\times 3\times 5\ldots(2i-1)}, \quad (=1 \text{ für } i=0)$$

*For further mathematical treatment of this subject, see the following papers by Ad. Schmidt: Erdmagnetismus, Encykl. Math. Wiss, **6**, 1, 10, 266-396 (1917), and Allgemeine Formeln zur Vereinfachung häufig wiederholter Potential-berechnungen durch Benutzung fester Stationsgruppen, Archiv Erdmag., Heft 5; Veröff. Preuss. Met. Inst. Nr. 332 (Abh. **8**, Nr. 2) 5-21 (1925).—*Ed.*

[1]Ad. Schmidt, Arch. Erdmag., Heft 5; Berlin, Abh. Met. Inst., **8**, Nr. 2, 14-15 (1925).

[2]Damit sind natürlich nicht alle von den verschiedenen Autoren benutzten Arten erschöpft. Es fehlen so z. B. die von Ad. Schmidt einmal gebrauchten streng normierten $R_n^m = P_n^m \sqrt{2n+1}$, ferner auch die von Adams, Helmholtz u. a. eingeführten Funktionen.

TABELLE 1—*Werte* p_n^m, $p_{n,m}$ *und* q_n^m

Werte	p_n^m					$p_{n,m}$					q_n^m				
$n \backslash m$	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
1	1.00000 0.00000	1.00000 0.00000*				1.00000 0.00000	1.00000 0.00000*				1.00000 0.00000	1.00000 0.00000*			
2	1.50000 0.17609	1.73205 0.23856	0.86602 9.93753			1.50000 0.17609	3.00000 0.47712	3.00000 0.47712			1.00000 0.00000	0.57735 9.76144	0.28868 9.46041		
3	2.50000 0.39794	3.06186 0.48599	1.93649 0.28702	0.79057 9.89794		2.50000 0.39794	7.50000 0.87506	15.00000 1.17609	15.00000 1.17609		1.00000 0.00000	0.40825 9.61092	0.12910 9.11092	0.05270 8.72185	
4	4.37500 0.64098	5.53399 0.74304	3.91312 0.59252	2.09165 0.32049	0.73951 9.86894	4.37500 0.64098	17.50000 1.24304	52.50000 1.72016	105.00000 2.02119	105.00000 2.02119	1.00000 0.00000	0.31623 9.50000	0.07454 8.87236	0.01992 8.29930	0.00704 7.84775

*Logarithmen.

Somit ergibt sich für den Übergang von den Gaussschen zu den Neumannschen Funktionen

$$P^{n,m}\, p_{n,m} = P_{n,m};\; p_{n,m} = \frac{1\times 3\times 5\ \ldots\ (2n-1)}{(n-m)\,!}$$

zu den Schmidtschen

$$P^{n,m}\, p_n^{\,m} = P_n^{\,m};\; p_n^{\,m} = 1\times 3\times 5\ \ldots (2n-1)\ \sqrt{\frac{\epsilon_m}{(n+m)!\,(n-m)!}},\ \epsilon_0 = 1;$$

$$\epsilon_m = 2,\ m \neq 0,\ \epsilon_{-m} = -\epsilon_m$$

Ferner für den Übergang von den Neumannschen zu den Schmidtschen

$$P_{n,m}\, q_n^{\,m} = P_{n,m}\, \frac{p_n^{\,m}}{p_{n,m}} = P_n^{\,m};\; q_n^{\,m} = \sqrt{\epsilon_m \frac{(n-m)\,!}{(n+m)\,!}}$$

In der Tabelle 1 sind die Werte der Umrechnungsfaktoren $p_n^{\,m}$, $p_{n,m}$, $q_n^{\,m}$ nebst ihrer Logarithmen bis zur vierten Ordnung einschliesslich angegeben[3].

TABELLE 2—*Liste der Observatorien*

Ort	Geogr. Breite ϕ		Geogr. Länge λ östl. v. Grw.		Polabstand θ	
	°	′	°	′	°	′
Pavlovsk	59	41	30	29	30	19
Sitka	57	03	224	40	32	57
Katharinenburg	56	50	60	38	33	10
Rude Skov	55	51	12	27	34	09
Eskdalmuir	55	19	356	48	34	41
Stonyhurst	53	51	357	32	36	09
Potsdam	52	23	13	04	37	37
Seddin	52	17	13	01	37	43
DeBilt	52	06	5	11	37	54
Niemegk	52	04	12	30	37	56
Greenwich	51	28	0	00	38	32
Abinger	51	11	359	37	38	49
Val Joyeux	48	49	2	01	41	11
Baldwin	38	47	264	50	51	13
Cheltenham	38	44	283	10	51	16
Tucson	32	15	249	10	57	45
Honolulu	21	19	201	56	68	41
San Juan	18	23	293	53	71	37
Vieques	18	09	294	33	71	51
Batavia	− 6	11	106	50	96	11
Huancayo	−12	03	284	40	102	03
Samoa	−13	48	188	14	103	48
Mauritius	−20	06	57	33	110	06
Watheroo	−30	19	115	52	120	19
Christchurch	−43	32	172	37	133	32
Orcadas	−60	43	315	13	150	43

[3]Weitere Werte der Umrechnungsfaktoren findet man noch bei Ad. Schmidt, *loc. cit.* p. 14-15; ferner ders. Aus d. Arch. Seewarte, **21**, 6-7 (1898).

TABELLE 3A—P_n^m

Ort	P_1^0	P_1^1	P_2^0	P_2^1	P_2^2	P_3^0	P_3^1	P_3^2	P_3^3	P_4^0	P_4^1	P_4^2	P_4^3	P_4^4
Pavlovsk......	0.86325	0.50478	0.61780	0.75474	0.22066	0.31336	0.84264	0.42594	0.10168	0.01003	0.76353	0.60058	0.23224	0.04801
Sitka........	0.83914	0.54391	0.55625	0.79054	0.25620	0.21852	0.83962	0.48073	0.12721	−0.09628	0.69610	0.64979	0.28242	0.06472
Katharinenburg	0.83708	0.54708	0.55106	0.79319	0.25920	0.21075	0.83872	0.48515	0.12944	−0.10457	0.68967	0.65334	0.28668	0.06624
Rude Skov...	0.82757	0.56136	0.52731	0.80465	0.27291	0.17560	0.83341	0.50502	0.13985	−0.14118	0.65893	0.66838	0.30621	0.07344
Eskdalemuir..	0.82231	0.56904	0.51429	0.81047	0.28042	0.15664	0.82968	0.51563	0.14567	−0.16031	0.64122	0.67579	0.31692	0.07754
Stonyhurst .	0.80748	0.58990	0.47802	0.82503	0.30136	0.10500	0.81643	0.54413	0.16228	−0.21014	0.58900	0.69332	0.34670	0.08955
Potsdam. .	0.79211	0.61038	0.44116	0.83742	0.32264	0.05434	0.79884	0.57148	0.17978	−0.25554	0.53210	0.70646	0.37676	0.10264
Seddin... .	0.79105	0.61176	0.43863	0.83819	0.32411	0.05093	0.79749	0.57329	0.18100	−0.25847	0.52807	0.70719	0.37882	0.10358
DeBilt... .	0.78908	0.61429	0.43398	0.83956	0.32679	0.04469	0.79495	0.57661	0.18325	−0.26378	0.52062	0.70847	0.38258	0.10530
Niemegk. .	0.78873	0.61474	0.43313	0.83981	0.32728	0.04356	0.79448	0.57720	0.18366	−0.26473	0.51926	0.70869	0.38326	0.10561
Greenwich. .	0.78224	0.62297	0.41786	0.84405	0.33610	0.02329	0.78570	0.58789	0.19114	−0.28152	0.49442	0.71232	0.39558	0.11138
Abinger... .	0.77916	0.62683	0.41062	0.84593	0.34028	0.01380	0.78131	0.59284	0.19471	−0.28916	0.48248	0.71376	0.40139	0.11417
Val Joyeux.. .	0.75261	0.65847	0.34962	0.85835	0.37549	−0.06319	0.73875	0.63191	0.22571	−0.34544	0.37804	0.71864	0.44943	0.13902
Baldwin..... .	0.62638	0.77952	0.08852	0.84571	0.52624	−0.32517	0.45910	0.73706	0.37447	−0.42283	−0.09788	0.59324	0.62059	0.27306
Cheltenham.. .	0.62570	0.78007	0.08724	0.84539	0.52698	−0.32615	0.45738	0.73730	0.37526	−0.42256	−0.10014	0.59205	0.62123	0.27382
Tucson .. .	0.53362	0.84573	−0.07288	0.78166	0.61943	−0.42056	0.21945	0.73910	0.47823	−0.33807	−0.35920	0.39713	0.67516	0.37833
Honolulu	0.36352	0.93159	−0.30178	0.58656	0.75158	−0.42519	−0.19354	0.61093	0.63916	−0.04416	−0.55552	−0.03637	0.61474	0.55698
San Juan.	0.31537	0.94897	−0.35081	0.51837	0.77989	−0.39464	−0.29213	0.54998	0.67561	0.04530	−0.54508	−0.15293	0.56373	0.59972
Vieques..	0.31151	0.95024	−0.35445	0.51270	0.78199	−0.39169	−0.29958	0.54469	0.67834	0.05231	−0.54308	−0.16190	0.55906	0.60295
Batavia..	−0.10771	0.99418	−0.48260	−0.18547	0.85598	0.15844	−0.57349	−0.20616	0.77685	0.33208	0.24710	−0.50766	−0.22138	0.72245
Huancayo	−0.20877	0.97797	−0.43463	−0.35362	0.82828	0.29040	−0.46837	−0.38665	0.73945	0.27987	0.43498	−0.37154	−0.40843	0.67645
Samoa .	−0.23853	0.97113	−0.41465	−0.40122	0.81675	0.32387	−0.42551	−0.43564	0.72406	0.17579	0.47646	−0.31723	−0.45696	0.65775
Mauritius..	−0.34366	0.93909	−0.32285	−0.55898	0.76374	0.41402	−0.23549	−0.58690	0.65474	−0.00686	0.55449	−0.08543	−0.59531	0.57515
Watheroo.	−0.50478	0.86325	−0.11780	−0.75474	0.64536	0.43562	0.14485	−0.72843	0.50857	−0.29646	0.41903	0.32644	−0.67920	0.41067
Christchurch	−0.68878	0.72497	0.21162	−0.86489	0.45517	0.21625	0.60913	−0.70103	0.30124	−0.41938	−0.12668	0.68191	−0.54895	0.20428
Orcadas......	−0.87221	0.48913	0.64113	−0.73893	0.20719	−0.35053	0.83981	−0.40410	0.09251	0.05419	−0.78426	0.57848	−0.21349	0.04233

TABELLE 3B—*Logarithmen* P_n^m

Ort	lg P_1^0	lg P_1^1	lg P_2^0	lg P_2^1	lg P_2^2	lg P_3^0	lg P_3^1	lg P_3^2	lg P_3^3	lg P_4^0	lg P_4^1	lg P_4^2	lg P_4^3	lg P_4^4
Pavlovsk	9.93614	9.70310	9.79085	9.87780	9.34373	9.49604	9.92564	9.62935	9.00724	8.00147	9.88282	9.77857	9.36593	8.68135
Sitka	9.92384	9.73552	9.74527	9.89792	9.40858	9.33950	9.92408	9.68190	9.10452	8.98354n	9.84267	9.81278	9.45090	8.81104
Katharinenburg	9.92277	9.73805	9.74120	9.89938	9.41363	9.32377	9.92362	9.68588	9.11208	9.01940n	9.83864	9.81514	9.45740	8.82114
Rude Skov	9.91780	9.74924	9.72206	9.90561	9.43602	9.24452	9.92086	9.70331	9.14567	9.14976n	9.81884	9.82502	9.48602	8.86592
Eskdalemuir	9.91504	9.75514	9.71121	9.90874	9.44782	9.19489	9.91891	9.71234	9.16337	9.20497n	9.80701	9.82981	9.50095	8.88952
Stonyhurst	9.90713	9.77078	9.67945	9.91647	9.47909	9.02121	9.91192	9.73570	9.21028	9.32251n	9.77012	9.84094	9.53996	8.95206
Potsdam	9.89879	9.78560	9.64460	9.92294	9.50872	8.73514	9.90246	9.75700	9.25473	9.40746n	9.72599	9.84909	9.57607	9.01133
Seddin	9.89820	9.78658	9.64210	9.92334	9.51069	8.70698	9.90172	9.75838	9.25768	9.41241n	9.72269	9.84953	9.57843	9.01526
De Bilt	9.89712	9.78837	9.63747	9.92405	9.51427	8.65020	9.90034	9.76088	9.26305	9.42124n	9.71652	9.85032	9.58272	9.02242
Niemegk	9.89693	9.78869	9.63662	9.92418	9.51492	8.63906	9.90008	9.76133	9.26402	9.42281n	9.71538	9.85046	9.58350	9.02372
Greenwich	9.89334	9.79447	9.62103	9.92637	9.52646	8.36714	9.89526	9.76929	9.28134	9.44950n	9.69410	9.85268	9.59723	9.04681
Abinger	9.89162	9.79715	9.61344	9.92733	9.53183	8.13982	9.89282	9.77294	9.28939	9.46113n	9.68348	9.85355	9.60356	9.05754
Val Joyeux	9.87657	9.81854	9.54360	9.93366	9.57460	8.80063n	9.86850	9.80066	9.35355	9.53838n	9.57754	9.85651	9.65266	9.14309
Baldwin	9.79684	9.89183	8.94705	9.92722	9.72118	9.51211n	9.66190	9.86751	9.57342	9.62617n	8.99069n	9.77323	9.79281	9.43625
Cheltenham	9.79636	9.89213	8.94074	9.92706	9.72179	9.51342n	9.66028	9.86764	9.57434	9.62589n	9.00060n	9.77236	9.79325	9.43747
Tucson	9.72723	9.92723	8.86263n	9.89302	9.79199	9.62383n	9.34133	9.86871	9.67963	9.52901n	9.55533n	9.59893	9.82941	9.57787
Honolulu	9.56053	9.96922	9.47969n	9.76831	9.87598	9.62858n	9.28677n	9.78599	9.80561	8.64498n	9.74470n	8.56071n	9.78869	9.74584
San Juan	9.49882	9.97725	9.54507n	9.71464	9.89203	9.59620n	9.46558n	9.74034	9.82969	8.65613	9.73646n	9.18449n	9.75107	9.77795
Vieques	9.49347	9.97784	9.54955n	9.70986	9.89320	9.59294n	9.47651n	9.73615	9.83144	8.71859	9.73487n	9.20926n	9.74746	9.78028
Batavia	9.03226n	9.99747	9.68359n	9.26828n	9.93246	9.19987	9.75853n	9.31420n	9.89034	9.52125	9.39286	9.70557n	9.34514n	9.85881
Huancayo	9.31966n	9.99032	9.36812n	9.54854n	9.91818	9.46300	9.67059n	9.58732n	9.86891	9.34217	9.63847	9.57001n	9.61112n	9.83024
Samoa	9.37755n	9.98728	9.61769n	9.60339n	9.91209	9.51037	9.62891n	9.63912n	9.85978	9.24500	9.67803	9.50137n	9.65988n	9.81806
Mauritius	9.53613n	9.97271	9.50900n	9.74740n	9.88295	9.61702	9.37196n	9.76856n	9.81607	7.83630n	9.74389	8.93160n	9.77474n	9.75978
Watheroo	9.70310n	9.93614	9.07114n	9.87780n	9.80980	9.63911	9.16092	9.86239n	9.70635	9.47197n	9.62225	9.51380	9.83200n	9.61349
Christchurch	9.83808n	9.86032	9.32556	9.93696n	9.65818	9.33496	9.78471	9.84574n	9.47891	9.62261n	9.10270n	9.83372	9.73953n	9.31023
Orcadas	9.94062n	9.68942	9.80695	9.86861n	9.31638	9.54472n	9.92418	9.60648n	8.96621	8.73389	9.89446n	9.76229	9.32938n	8.62664

Tabelle 4a—X_n^m

Ort	X_2^0	X_2^1	X_2^2	X_3^0	X_3^1	X_3^2	X_3^3	X_4^0	X_4^1	X_4^2	X_4^3	X_4^4
Pavlovsk	−0.65362	0.42470	0.37737	−0.68801	0.03136	0.40260	0.17389	−0.60362	−0.31057	0.29630	0.26392	0.08211
Sitka	−0.68462	0.35362	0.39527	−0.68555	−0.07494	0.39059	0.19626	−0.55032	−0.42072	0.23707	0.28103	0.09985
Katharinenburg	−0.68692	0.34763	0.39659	−0.68482	−0.08362	0.38920	0.19806	−0.54523	−0.42915	0.23167	0.28215	0.10136
Rude Skov	−0.69685	0.32021	0.40233	−0.68048	−0.12279	0.38215	0.20617	−0.52093	−0.46607	0.20623	0.28664	0.10826
Eskdalemuir	−0.70189	0.30518	0.40524	−0.67743	−0.14387	0.37781	0.21050	−0.50693	−0.48513	0.19183	0.28866	0.11205
Stonyhurst	−0.71450	0.26330	0.41251	−0.66662	−0.20105	0.36405	0.22214	−0.46565	−0.53382	0.15021	0.29261	0.12258
Potsdam	−0.72523	0.22073	0.41871	−0.65225	−0.25682	0.34763	0.23330	−0.42066	−0.57668	0.10598	0.29413	0.13320
Seddin	−0.72589	0.21781	0.41909	−0.65115	−0.26057	0.34642	0.23404	−0.41747	−0.57938	0.10287	0.29414	0.13393
De Bilt	−0.72708	0.21244	0.41978	−0.64908	−0.26741	0.34416	0.23540	−0.41158	−0.58426	0.09716	0.29413	0.13526
Niemegk	−0.72730	0.21146	0.41990	−0.64869	−0.26865	0.34375	0.23564	−0.41051	−0.58513	0.09612	0.29412	0.13550
Greenwich	−0.73097	0.19383	0.42203	−0.64152	−0.29083	0.33607	0.24000	−0.39088	−0.60032	0.07719	0.29378	0.13986
Abinger	−0.73260	0.18547	0.42296	−0.63793	−0.30119	0.33229	0.24203	−0.38144	−0.60713	0.06814	0.29346	0.14191
Val Joyeux	−0.74335	0.11504	0.42918	−0.60319	−0.38464	0.29721	0.25798	−0.29887	−0.65421	−0.00972	0.28696	0.15890
Baldwin	−0.73241	0.18646	0.42286	−0.37485	−0.65397	0.08909	0.30090	0.07738	−0.64889	−0.34216	0.18092	0.21941
Cheltenham	−0.73213	−0.18793	0.42269	−0.37345	−0.65489	0.08786	0.30100	0.07917	−0.64804	−0.34366	0.18009	0.21964
Tucson	−0.67694	−0.37283	0.39083	−0.17918	−0.73293	−0.07958	0.30174	0.28397	−0.47788	−0.50628	0.05198	0.23871
Honolulu	−0.50798	−0.63714	0.29328	0.15802	0.66915	−0.36294	0.24941	0.43918	−0.01562	−0.58213	−0.21393	0.21734
San Juan	−0.44892	0.69376	0.25918	0.25852	−0.61209	−0.42978	0.22453	0.43092	0.11692	−0.55273	−0.28356	0.19931
Vieques	−0.44401	0.69795	0.25635	0.24460	−0.60689	−0.43482	0.22237	0.42935	0.12722	−0.54949	0.28890	0.19766
Batavia	0.16062	0.84593	−0.09274	0.46825	0.23802	−0.61940	−0.08416	−0.19535	0.53176	0.23458	−0.49286	−0.07827
Huancayo	0.30625	−0.79054	−0.17681	0.38243	0.44090	−0.54874	−0.15785	−0.34388	0.37087	0.42171	−0.41294	−0.14440
Samoa	0.34747	−0.76748	−0.20061	0.34743	0.49404	−0.51986	−0.17785	−0.37668	0.30722	0.46640	−0.38092	−0.16156
Mauritius	0.48409	−0.66147	−0.27949	0.19227	0.64737	−0.39141	−0.23960	−0.43836	0.03988	0.57249	−0.24330	−0.21048
Watheroo	0.65362	0.42470	0.37737	−0.11827	0.73960	−0.13128	−0.29738	−0.33128	−0.40749	0.53989	0.00748	−0.24013
Christchurch	0.74902	−0.04432	−0.43245	−0.49736	0.54605	0.19806	−0.28620	0.10015	−0.69318	0.18957	0.24671	−0.19408
Orcadas	0.63994	0.45164	−0.36947	−0.68570	−0.07323	0.40485	−0.16497	0.62001	−0.26395	−0.31606	0.25559	−0.07548

Tabelle 4B—*Logarithmen X_n^m*

Ort	lg X_2^0	lg X_2^1	lg X_2^2	lg X_3^0	lg X_3^1	lg X_3^2	lg X_3^3	lg X_4^0	lg X_4^1	lg X_4^2	lg X_4^3	lg X_4^4
Pavlovsk	9.81533n	9.62808	9.57677	9.83760n	8.49639	9.60487	9.24028	9.78076n	9.49216n	9.47174	9.42147	8.91438
Sitka	9.83545n	9.54854	9.59689	9.83604n	8.87473n	9.59172	9.29283	9.74061n	9.62400n	9.37488	9.44875	8.99936
Katharinenburg	9.83691n	9.54112	9.59835	9.83557n	8.92232n	9.59017	9.29680	9.73658n	9.63261n	9.36487	9.45048	9.00586
Rude Skov	9.84314n	9.50543	9.60458	9.83281n	9.08917n	9.58223	9.31423	9.71678n	9.66845n	9.31436	9.45734	9.03448
Eskdalemuir	9.84627n	9.48455	9.60771	9.83087n	9.15796n	9.57728	9.32326	9.70495n	9.68586n	9.28292	9.46038	9.04941
Stonyhurst	9.85400n	9.42045	9.61544	9.82388n	9.30330n	9.56116	9.34663	9.66806n	9.72740n	9.17670	9.46629	9.08841
Potsdam	9.86048n	9.34387	9.62191	9.81442n	9.40963n	9.54112	9.36792	9.62393n	9.76094n	9.02520	9.46853	9.12452
Seddin	9.86087n	9.33808	9.62231	9.81368n	9.41592n	9.53960	9.36930	9.62063n	9.76296n	9.01230	9.46855	9.12688
De Bilt	9.86158n	9.32724	9.62302	9.81230n	9.42718n	9.53676	9.37180	9.61446n	9.76660n	8.98750	9.46853	9.13118
Niemegk	9.86171n	9.32524	9.62315	9.81204n	9.42918n	9.53624	9.37225	9.61332n	9.76725n	8.98282	9.46853	9.13195
Greenwich	9.86390n	9.28742	9.62534	9.80721n	9.46364n	9.52643	9.38022	9.59204n	9.77838n	8.88757	9.46802	9.14569
Abinger	9.86486n	9.26828	9.62630	9.80478n	9.47884n	9.52152	9.38386	9.58142n	9.78328n	8.83342	9.46756	9.15202
Val Joyeux	9.87120n	9.06083	9.63263	9.78045n	9.58505n	9.47306	9.41158	9.47548n	9.81572n	7.98759n	9.45782	9.20112
Baldwin	9.86475n	9.27058n	9.62619	9.57386n	9.81556n	8.94981	9.47843	8.88863	9.81217n	9.53423n	9.25749	9.34126
Cheltenham	9.86459n	9.27400n	9.62603	9.57223n	9.81617n	8.94380	9.47857	8.89854	9.81160n	9.53613n	9.25550	9.34170
Tucson	9.83055n	9.57152n	9.59199	9.25329n	9.86506n	8.90078n	9.47963	9.45327	9.67932n	9.70439n	8.71584	9.37786
Honolulu	9.70584n	9.80423n	9.46728	9.19872	9.82552n	9.55984n	9.39692	9.64264	8.19373n	9.76502n	9.33027n	9.33714
San Juan	9.65217n	9.84121n	9.41361	9.37753	9.78681n	9.63325n	9.35127	9.63440	9.06788	9.74251n	9.45264n	9.29952
Vieques	9.64739n	9.84383n	9.40883	9.38846	9.78311n	9.63831n	9.34708	9.63281	9.10455	9.73996n	9.46075n	9.29592
Batavia	9.20581	9.92734n	8.96725n	9.67048	9.37662	9.79197n	8.92513n	9.29080n	9.72572	9.37030	9.69272n	8.89360n
Huancayo	9.48607	9.89792n	9.24751n	9.58255	9.64434	9.73936n	9.19825n	9.53641n	9.56922	9.62501	9.61588n	9.15957n
Samoa	9.54092	9.88506n	9.30236n	9.54086	9.69376	9.71589n	9.25005n	9.57597n	9.48744	9.66876	9.58083n	9.20833n
Mauritius	9.68493	9.82051n	9.44637n	9.28392	9.81115	9.59263n	9.37949n	9.64183n	8.60077	9.75777	9.38614n	9.32320n
Watheroo	9.81533	9.62808n	9.57677n	9.07287n	9.86900	9.11820n	9.47331n	9.52019n	9.61012n	9.73231	7.87415	9.38045n
Christchurch	9.87449	8.64658n	9.63593n	9.69667n	9.73723	9.29680	9.45666n	9.00064	9.84085n	9.27777	9.39218	9.28799n
Orcadas	9.80614	9.65479	9.56758n	9.83613n	8.86467n	9.60729	9.21741n	9.79240	9.42151n	9.49977n	9.40755	8.87784n

TABELLE 5A—Y_n^m

Ort	Y_2^1	Y_2^2	Y_3^1	Y_3^2	Y_3^3	Y_4^1	Y_4^2	Y_4^3	Y_4^4
Pavlovsk	0.74760	0.43715	0.55644	0.56255	0.20144	0.37815	0.59489	0.34506	0.09512
Sitka	0.72672	0.47104	0.51456	0.58923	0.23388	0.31995	0.59734	0.38944	0.11899
Katharinenburg	0.72493	0.47378	0.51103	0.59121	0.23661	0.31516	0.59712	0.39302	0.12108
Rude Skov	0.71670	0.48615	0.49487	0.59975	0.24913	0.29345	0.59532	0.40911	0.13082
Eskdalemuir	0.71214	0.49280	0.48601	0.60409	0.25599	0.28171	0.59380	0.41771	0.13626
Stonyhurst	0.69929	0.51087	0.46134	0.61494	0.27510	0.24962	0.58766	0.44080	0.15180
Potsdam	0.68599	0.52860	0.43626	0.62418	0.29453	0.21794	0.57871	0.46295	0.16816
Seddin	0.68506	0.52980	0.43453	0.62475	0.29587	0.21580	0.57800	0.46442	0.16931
De Bilt	0.68336	0.53199	0.43137	0.62577	0.29832	0.21188	0.57666	0.46710	0.17142
Neimegk	0.68306	0.53238	0.43079	0.62596	0.29876	0.21117	0.57641	0.46759	0.17180
Greenwich	0.67744	0.53951	0.42040	0.62912	0.30681	0.19841	0.57172	0.47624	0.17879
Abinger	0.67477	0.54285	0.41548	0.63052	0.31063	0.19243	0.56934	0.48026	0.18214
Val Joyeux	0.65178	0.57025	0.37397	0.63978	0.34278	0.14353	0.54569	0.51191	0.21113
Baldwin	0.54246	0.67508	0.19632	0.63036	0.48039	−0.03139	0.38052	0.59709	0.35029
Cheltenham	0.54187	0.67556	0.19545	0.63012	0.48107	−0.03209	0.37948	0.59728	0.35103
Tucson	0.46212	0.73242	0.08649	0.58262	0.56546	−0.10618	0.23478	0.59874	0.44734
Honolulu	0.31482	0.80678	−0.06925	0.43720	0.68610	−0.14908	−0.01952	0.49491	0.59788
San Juan	0.27312	0.82183	−0.10261	0.38637	0.71194	−0.14360	−0.08058	0.44553	0.63197
Vieques	0.26977	0.82293	−0.10509	0.38214	0.71386	−0.14288	−0.08519	0.44125	0.63453
Batavia	−0.09328	0.86099	−0.19228	−0.13824	0.78140	0.06214	−0.25532	−0.16701	0.72668
Huancayo	−0.18080	0.84694	−0.15964	−0.26358	0.75611	0.11119	−0.18996	−0.31322	0.69170
Samoa	−0.20658	0.84103	−0.14605	−0.29906	0.74559	0.12266	−0.16333	−0.35290	0.67730
Mauritius	−0.29762	0.81328	−0.08359	−0.41664	0.69720	0.14761	−0.04548	−0.47544	0.61245
Watheroo	−0.43715	0.74760	0.05593	−0.56255	0.58913	0.12135	0.18907	−0.59010	0.47572
Christchurch	−0.59650	0.62785	0.28007	−0.64465	0.41551	−0.04368	0.47030	−0.56790	0.28178
Orcadas	−0.75536	0.42360	0.57232	−0.55077	0.18914	−0.40084	0.59133	−0.32735	0.08654

Tabelle 5b—*Logarithmen* Y_n^m

Ort	lg Y_2^1	lg Y_2^2	lg Y_3^1	lg Y_3^2	lg Y_3^3	lg Y_4^1	lg Y_4^2	lg Y_4^3	lg Y_4^4
Pavlovsk	9.87367	9.64063	9.74542	9.75016	9.30414	9.57766	9.77444	9.53789	8.97825
Sitka	9.86137	9.67306	9.71144	9.77029	9.36899	9.50509	9.77622	9.59044	9.07552
Katharinenburg	9.86030	9.67558	9.70845	9.77174	9.37404	9.49853	9.77606	9.59441	9.08309
Rude Skov	9.85534	9.68677	9.69449	9.77797	9.39643	9.46754	9.77475	9.61184	9.11667
Eskdalemuir	9.85256	9.69267	9.68665	9.78110	9.40823	9.44980	9.77364	9.62087	9.13437
Stonyhurst	9.84466	9.70831	9.66402	9.78883	9.43950	9.39728	9.76913	9.64424	9.18128
Potsdam	9.83632	9.72313	9.63974	9.79531	9.46913	9.33834	9.76246	9.66553	9.22574
Seddin	9.83573	9.72411	9.63802	9.79571	9.47110	9.33405	9.76192	9.66691	9.22868
De Bilt	9.83465	9.72590	9.63485	9.79642	9.47468	9.32609	9.76092	9.66941	9.23405
Niemegk	9.83446	9.72622	9.63427	9.79654	9.47533	9.32463	9.76073	9.66986	9.23503
Greenwich	9.83087	9.73200	9.62367	9.79874	9.48687	9.29757	9.75718	9.67783	9.25234
Abinger	9.82915	9.73468	9.61855	9.79970	9.49224	9.28427	9.75537	9.68147	9.26039
Val Joyeux	9.81410	9.75607	9.57284	9.80603	9.53501	9.15694	9.73694	9.70919	9.32455
Baldwin	9.73437	9.82936	9.29296	9.79959	9.68159	8.49680n	9.58037	9.77604	9.54442
Cheltenham	9.73389	9.82966	9.29103	9.79942	9.68220	8.50641n	9.57920	9.77618	9.54534
Tucson	9.66476	9.86476	8.93698	9.76538	9.75240	9.02604n	9.37067	9.77724	9.65064
Honolulu	9.49806	9.90675	8.84043n	9.64068	9.83639	9.17342n	8.29046n	9.69453	9.77661
San Juan	9.43636	9.91478	9.01120n	9.58700	9.85244	9.15715n	8.90620n	9.64888	9.80070
Vieques	9.43100	9.91536	9.02155n	9.58223	9.85361	9.15497n	8.93039n	9.64469	9.80245
Batavia	8.96979n	9.93500	9.28394n	9.14065n	9.89287	8.79334	9.40708n	9.22274n	9.86134
Huancayo	9.25719n	9.92785	9.20315n	9.42091n	9.87859	9.04608	9.27865n	9.49586n	9.83992
Samoa	9.31508n	9.92481	9.16451n	9.47575n	9.87250	9.08869	9.21306n	9.54766n	9.83078
Mauritius	9.47366n	9.91024	8.92214n	9.61976n	9.84336	9.16912	8.65786n	9.67710n	9.78707
Watheroo	9.64063n	9.87367	8.74766	9.75016n	9.77021	9.08405	9.27663	9.77092n	9.67735
Christchurch	9.77561n	9.79785	9.44727	9.80932n	9.61858	8.64031n	9.67237	9.75427n	9.44991
Orcadas	9.87815n	9.62695	9.75764	9.74097n	9.27679	9.60298n	9.77183	9.51502n	8.93721

Setzt man nun das Potential für die erdmagnetischen Erscheinungen in üblicher Form an:

$$V = \Sigma\Sigma \left[R \left(c_n^m (t) \cos m\,\phi + s_n^m (t) \sin m\,\phi \right) P_n^m \left(\frac{B}{\gamma} \right)^{n+1} + R \left(\gamma_n^m (t) \cos m\,\phi + \sigma_n^m (t) \sin m\,\phi \right) P_n^m \left(\frac{\gamma}{R} \right)^{n} \right]$$

so hat man in den $c_n^m\ (t)$, $s_n^m\ (t)$, und $\gamma_n^m\ (t)$, $\sigma_n^m\ (t)$ die inneren und aüsseren Ursachen des erdmagnetischen Feldes getrennt vor sich. Für die Kraftkomponenten folgt in herkömmlicher Bezeichnungsweise an der Erdoberfläche

$$X = -\Sigma\Sigma\,(g_n^m \cos m\,\phi + h_n^m \sin m\,\phi)\; n\,X_n^m;\quad n\,X_n^m = \frac{\partial}{\partial\theta} P_n^m$$

$$Y = -\Sigma\Sigma\,(-g_n^m \sin m\,\phi + h_n^m \cos m\,\phi)\; n\,Y_n^m;\quad n\,Y_n^m = \frac{m}{\sin\theta} P_n^m$$

$$g_n^m = c_n^m + \gamma_n^m;\quad h_n^m = s_n^m + \sigma_n^m$$

$$Z = -\Sigma\Sigma\,[-c_n^m \cos m\,\phi + s_n^m \sin m\,\phi)\; n\,Z_n^m + (\gamma_n^m \cos m\,\phi + \sigma_n^m \sin m\,\phi)\; n\,P_n^m];\quad n\,Z_n^m = (n+1)\,P_n^m$$

Die in diesen Formeln auftretenden Funktionen P_n^m, X_n^m, Y_n^m sowie ihre Logarithmen sind in den folgenden Tabellen für die wichtigsten Observatorien berechnet worden. Tabelle 2 gibt eine Übersicht der 26 Observatorien mit ihren geographischen Koordinaten. Die Reihe der Observatorien wird noch weiter vervollständigt. Die grundlegenden P_n^m-Werte wurden auf zwei verschiedenen Wegen getrennt berechnet. Einmal nach der für numerische Rechnung weniger bequemen Formel (1), ferner nach der weitaus bequemeren Partialproduktformel. Die hierfür erforderlichen Nullstellen der Kugelfunktionen sind seinerzeit von Ad. Schmidt berechnet worden[4], und konnten hier also ohne weiteres benutzt werden. Gerechnet wurde sechsstellig und als Differenz bei den beiden Rechnungsarten nur drei Einheiten der sechsten Dezimale zugelassen. In der Tabelle sind durchgehends nur 5 Stellen angegeben, eine Genauigkeit, die ja für die meisten Zwecke vollständig ausreicht. Die Sicherheit der fünften Stelle ist im allgemeinen gewährleistet bis auf die üblichen Aufrundungserscheinungen, wodurch ein formaler Fehler von höchstens 0.5 Einheiten dieser Dezimale möglich ist.

Zwischen den P_n^m, X_n^m, Y_n^m bestehen eine Reihe wohlbekannter Beziehungen, die für die verschiedenen Funktionsarten hier noch einmal übersichtlich zusammengestellt werden sollen.

Rekursionsformeln für gleiches m

$$P^{n+1,\,m} - c\,P^{n,\,m} + \frac{(n+m)\,(n-m)}{(2n-1)\,(2n+1)} P^{n-1,\,m} = 0$$

$$(n-m+1),\ P_{n+1,\,m} - (2n+1)\,c\,P_{n,\,m} + (n+m)\,P_{n-1,\,m} = 0$$

$$P_{n+1}^m \sqrt{(n+m+1)\,(n-m+1)} - (2n+1)\,c\,P_n^m + \sqrt{(n-m)\,(n+m)}\,P_{n-1}^m = 0$$

[4] Ad. Schmidt, Aus d. Arch. Seewarte, **21**, 5 (1898).

Rekursionsformeln für gleiches n

$$(n-m)\, P^{n,\, m+1} - 2m \frac{c}{s}\, P^{n,\, m} + (n+m)\, P^{n,\, m-1} = 0$$

$$P_{n,\, m+1} - 2m \frac{c}{s}\, P_{n,\, m} + (n+m)\,(n-m+1)\, P_{n,\, m-1} = 0$$

$$\sqrt{\frac{(n-m)\,(n+m+1)}{\delta_{m+1}}}\, P_n^{\,m+1} - 2m \frac{c}{s}\, P_n^{\,m} +$$

$$\sqrt{\delta_m\,(n+m)\,(n-m+1)}\; P_n^{\,m-1} = 0, \quad \delta_m = \frac{\epsilon_m}{\epsilon_{m-1}}, \quad \delta_0 = \frac{1}{2}$$

Beziehungen der X zu den P

$$nX^{n,\, m} = \frac{n+m}{2}\, P^{n,\, m-1} - \frac{n-m}{2}\, P^{n,\, m+1}$$

$$nX_{n,\, m} = \frac{1}{2}\,(n+m)\,(n-m+1)\, P_{n,\, m-1} - \frac{1}{2}\, P_{n,\, m+1}$$

$$nX_n^{\,m} = \frac{1}{2}\sqrt{\delta_m\,(n+m)\,(n-m+1)}\; P_n^{\,m-1} - \frac{1}{2}\sqrt{\frac{(n-m)\,(n+m+1)}{\delta_{m+1}}}\; P_n^{\,m+1}$$

Beziehungen der Y zu den P

$$n\,Y^{n,\, m} = \frac{2n+1}{2}\left[I^{\,n+1,\, m-1} + P^{n+1,\, m+1}\right]$$

$$n\,Y_{n,\, m} = \frac{1}{2}\left[(n-m+1)\,(n-m+2)\, P_{n+1,\, m-1} + P_{n+1,\, m+1}\right]$$

$$n\,Y_n^{\,m} = \frac{1}{2}\Bigg[\sqrt{\delta_m\,(n-m+1)\,(n-m+2)}\; P_{n+1}^{\,m-1} +$$

$$\sqrt{\frac{(n+m+1)\,(n+m+2)}{\delta_{m+1}}}\; P_{n+1}^{\,m+1}\Bigg]$$

Man erkennt hieraus sofort, dass für die $X^{n,\, m}$ im speziellen gilt $X^{n,\, 0} = -P^{n,\, 1}$ und $X^{n,\, n} = P^{n,\, n-1}$. Daher sind aus Gründen der Platzersparnis in den Tabellen die Werte von $X_1^{\,0}$ und $X_1^{\,1}$ nicht mit aufgenommen worden. Ferner fehlt natürlich bei den $Y_n^{\,m}$ $Y_1^{\,1}$ 1 und $Y_n^{\,0} = 0$.

Die zum Teil nicht ganz einfachen und übersichtlichen Rechnungen sind von dem Rechner des Magnetischen Observatoriums Herrn L. Feist mit grosser Gewissenhaftigkeit ausgeführt worden. Die Tabellen die einen Teil einer grösseren Untersuchung über die Säkularvariation bilden, sind mit Unterstützung der Notgemeinschaft der Deutschen Wissenschaften ausgeführt worden, wofür ihr vom Verfasser an dieser Stelle der aufrichtigste Dank ausgesprochen sei.

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REVIEWS AND ABSTRACTS

(See also pages 430, 478, and 482)

Goldie, A. H. R.: *The electric field in terrestrial magnetic storms.* Edinburgh, Trans. R. Soc., v. 57, Pt. 1, No. 4, 1931 (143-177).

A theory of the cause of magnetic storms has been outlined by A. H. R. Goldie in this paper in which the diurnal variation of the Earth's magnetic field is attributed to an electric field which "appears to be generated mainly in the tropical and subtropical regions of the sunlit hemisphere" while the difference between quiet and disturbed conditions is explained as arising from differences of ionization of the conducting atmosphere in these regions. An attempt is made to demonstrate with data from Eskdalemuir, Greenwich, and Colába a tendency of "sudden commencements" to appear during the afternoon hours on local time and this is offered as a partial substantiation of the hypothesis that the disturbance may be attributed to an increase of ionization of the current-carrying regions. Further proof of the hypothesis is offered by pointing out certain similarities between the quiet-day and disturbed-day variations at Lerwick.

On the basis of data from Lerwick and Eskdalemuir principally, electric currents in the atmosphere which would produce the observed magnetic variations are computed and the disturbed-day current-system for northern latitudes is mapped. A theoretical examination of the air-motions and induced electromotive forces is found to admit of electric currents in the atmosphere such as are described.

Although the author is to be commended for this attack on a problem as intricate and as illusive as this it seems necessary to point out certain details of his deductions which are at variance with well established findings of other investigators as well as certain unorthodox procedures which he employs. First, the current-system which is shown does not appear adequate to explain the post-perturbation effect, so evident in the horizontal-intensity records of stations in lower latitudes. The currents were computed principally from the magnetic variations at two observatories alone and were assumed to exist entirely in the atmosphere. The concomitant induced currents within the Earth which, in times of rapid fluctuations of the magnetic field must be enormous, are disregarded. For this reason the computed current-system cannot be considered as a physical reality. Further, it appears from certain statements of the author as well as from the map of the current-system that part of the hypothetical current-flow is dissipated or consumed in the auroral zone, a supposition which is in violation of the necessary conditions of continuity.

Two misconceptions appear in the section in which the effect of the electric currents on the air-motions is treated. The author states that the chart of the current-system of the quiet-day variations as deduced by Chapman and illustrated by Bartels suggests that the currents have their origin in tropical latitudes. This is contrary to the theory supported by these two investigators which attributes the currents to electromotive forces induced by the motion of the air across the vertical component of the Earth's permanent field. As this component is extremely small in tropical latitudes the main electromotive forces cannot be generated there; in fact, for the idealized case, the currents flow against the feeble induced electromotive forces in tropical regions. The effectiveness of the electric currents in damping the air-motions as suggested in this paper is an intriguing but exceedingly complex subject, worthy of further investigation. The method of treatment which has been accorded it is, however, fallacious, for in the absence of the electric currents the air motions are not necessarily "along the isobars" as is stated. Although this condition obtains for ordinary air-motions, the oscillatory pressure and velocity-fields which give rise to the current-system of the magnetic variations are entirely different phenomena, migrating about the Earth, as they do, with a velocity approximately equal to that of sound.

Although the theory as developed in this paper is not a satisfactory explanation of magnetic storms in itself, certain features which have been brought out will undoubtedly prove valuable in other attempts at explanation of these illusive phenomena.

A. G. McNish

PROGRESS IN THE PHOTOGRAPHY OF THE AURORA BOREALIS

BY CARL STÖRMER

In pursuance of the collaboration of German and Norwegian scientists in the Aurora-Borealis investigations initiated by Dr. Brüche, the Notgemeinschaft der deutschen Wissenschaft, Heinrich Hertz Institute, and the AEG furnished the means for carrying out exhaustive research during the past winter on the instantaneous photography of the Aurora Borealis.

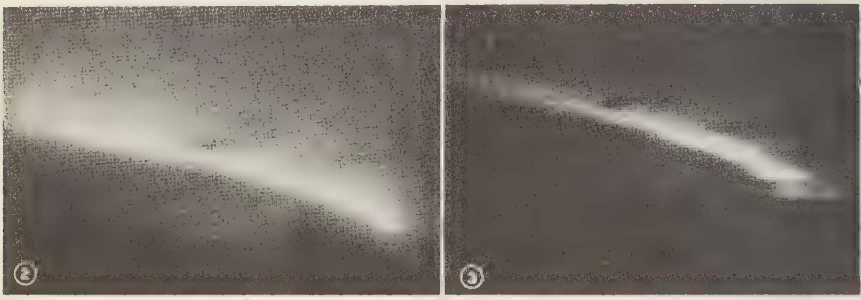
In this research work, reduction of the exposure-time is not only of profound importance from the standpoint of recording rapidly-moving phenomena, but is also the hypothesis for the employment of the cinematographic principle for recording the behaviour of the Aurora Borealis as a function of time, as used for establishing any possible correlation with other phenomena (fluctuations of ionized-region layers, rapid magnetic disturbances, etc.). In order to carry out the research work, Dipl. Ing. Bauer, assistant at the photophysical laboratory of the Danzig Technical University, worked as guest in the Aurora-Borealis Observatory at Tromsö from December 1931 to April 1932 with apparatus from the AEG Research Institute.

It is a pleasure to give a brief account of the chief results derived from this work, which led to successful cooperation with Director Harang and Tönsberg in the Aurora-Borealis Observatory. In view of the results already achieved, it is to be hoped that it will be continued during the coming winter.

By comparing different lenses, it could be verified that the Astro *RK* lens is so much superior to the next best lens obtainable and hitherto employed for photographing the Aurora Borealis, that it was possible to reduce the exposure-time to a third. By selecting suitable photographic emulsions and sensitizing the plate-material

FIG. 1—Portion of cinematographic film obtained at Tromsö in 1932, showing lowest aurora thus far photographed

according to the Schmiescheck principle, the exposure-time was again reduced to a fraction as compared with ordinary material. By means of these improvements, it was possible, in individual cases, to reduce the exposure-time below a tenth of previous times and thus obtain instantaneous photographs with exposure-times of less than one-half second, even with moderately bright Aurora Borealis.



FIGS. 2 AND 3—(2) Auroral arc of September 1, 1932, $16^h\ 30^m$ Central European time (Objective: Quartz achromat F: 1.2; plate: Cinechrom film; exposure: 30 seconds); (3) Auroral arc of September 1, 1932, $16^h\ 30^m$ Central European time (Objective: Astro R. K. F: 1.25; plate: Agfa infra-red 810 sensitized; exposure: 2 minutes; filter: Zeiss red-filter)

The great reduction of the exposure opened the way to many possibilities:

Aurora Borealis cinematography—With an exposure of about one second, the auroral displays were permanently recorded in the stage of formation and eclipse by means of the cinematographic camera. Such cinematographic recording, as had already been initiated some years ago by Krogness and the author with the then available expedients, was utilized to record the height of the Aurora Borealis by means of two cinematographic cameras, in that a simultaneous cinematographic record of the Aurora Borealis was carried out successfully by W. Bauer and Harang, the director of the Tromsö Observatory, from the two parallax stations, Tromsö and Tennes, situated 43 kilometers apart. On this occasion, it was possible to record the lowest Aurora-Borealis arc ever observed and which reached down to lower than 70 kilometers from the Earth's surface—a fact of great scientific interest.

Colour photography of the Aurora Borealis—The usual commercial color plates are so insensitive, that it has as yet been impossible to photograph the Aurora Borealis with them. However, it has been possible by means of the most powerful lenses and sensitized plates to take color photographs of tranquil arcs, these photographs showing the green color very true to nature.

The Aurora-Borealis spectrum—Particular success was achieved in reducing the exposure-times in respect of the Aurora-Borealis spectrum.[1] After filtering the visible and ultra-violet rays of light, the Aurora-Borealis arc was photographed on sensitized "Agfa" plates No. 810.

[1] W. Bauer, Naturw., **20**, 287-288 (1932).

FIG. 4—Auroral arc of April 2, 1932, $19^h\ 45^m$ Central European time, photographed by W. Bauer (Objective: Astro R. K. F: 1.25; plate: Agfa infra-red sensitized; exposure 3 minutes; filter: Zeiss red-filter)

By carefully considering the limit of sensitivity of the plate and the permeability of the filter, it could thus be verified that the Aurora-Borealis spectrum possesses a previously unknown amount of ultra-red between 7500 and 8400 Å, which is, irrefutably, an important discovery. In the meantime, with the aid of the Aurora-Borealis spectrographs in Tromsö, Messrs. Vegard[2] and Harang have instituted a detailed investigation of the spectrum by utilizing these sensitized plates and have established the limits of two bands at 7883 and 8095 Å. According to Vegard, this refers probably to bands of nitrogen.

In conclusion, it may be mentioned, that following the establishment by Bauer of the great strength of the *RK* lens, and following Harang's recommendations on behalf of the International Union of Geodesy and Geophysics, I have given instructions that 18 Aurora-Borealis cameras be equipped with such lenses for next year's work in all parts of the world. Thus this progress in Aurora-Borealis photography has already proved to be a direct asset for the international cooperation during the Polar Year of 1932-33.

We hope that, in spite of the economic depression, the German institutions and companies will be able to provide the necessary means also this coming winter, for the continuation of these investigations. It is particularly during the Polar Year that the collaboration in the Aurora-Borealis Observatory will be especially fruitful.

[2]L. Vegard, Naturw. **20**, 268-269 (1932).

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REVIEWS AND ABSTRACTS

(See also pages 430, 474, and 482)

HALLIDAY, E. C.: *The polarity of thunder-clouds.* London, Proc. R. Soc., A, v. 138, No. 834, 1932 (205-229).

An account has been given of a method of recording photographically the sudden changes of electrical field caused by a flash of lightning and at the same time of observing the flash visually, photographing it if possible and making a mark on the field-change record immediately after it took place.

An analysis has been made of 560 correlations of "nature of flash" with "sudden field change" made in this way, on the lines indicated by a study of the effects to be expected from lightning-flashes taking place from clouds where the positive charge of electricity was above the negative charge, and following on the work done by Wilson and Schonland on this subject. It has been shown that the field changes obtained when flashes of lightning took place from the cloud to the ground and when they took place in the cloud when it was at a distance from the observing-station were such as to support the view that the upper charge on a thunder-cloud is positive and the lower charge is negative.

The occurrence of "double" lightning-flashes has been discussed, together with the electrical effects which such a compound flash would produce.

The question of the exact significance of branching in a lightning-flash has been investigated, and it has been shown that negative electricity can travel from the cloud to the ground by way of a flash which branches towards the ground.

The conclusions arrived at have been supported by photographs of lightning-flashes illustrating the points considered.

AUTHOR

HEILAND, C. A., AND W. E. PUGH: *Theory and experiments concerning a new compensated magnetometer system.* New York, N. Y., Amer. Inst. Min. Metall. Eng., Tech. Pub. No. 483, 1932, 42 pp. 23 cm.

Temperature-compensations used in magnetic instruments are either magnetic or mechanical in nature. A new magnetic system for a vertical balance is described which embodies a steel frame, an aluminum spindle on the north side for temperature-compensation, and an invar spindle on the south side for latitude-adjustment.

In an uncompensated magnetic system, the temperature coefficient would be $T.C. = -\mu Z$, where μ is the temperature-coefficient of the magnetic moment, and Z the vertical intensity. If the system is mechanically compensated, the temperature coefficient is $T.C. = -Z_0\ (p+\mu)$, where Z_0 is the vertical intensity for which the system is adjusted, and p a mechanical temperature-coefficient expressing the combined action of all expanding masses.

As seen from the above formula, the system may be compensated by making p equal and opposite to μ. However, this adjustment holds strictly only for one latitude as $-Z_0p$ remains practically constant but $-Z_0\mu$ changes. Fortunately, the changes are not very great; a system adjusted for Colorado may be used virtually throughout the United States, without mechanical readjustment.

There is no influence of temperature on scale-value, except when the movement of the scale-value screw is not at right-angles to the magnetic axis of the system.

Very elaborate experiments were conducted to determine the influence of temperature on reading and scale-value, for various latitudes and scale-values. The variations in position of the magnetic system with temperature, the daily variation, the temperature, and the time were recorded simultaneously. The temperature-gradient employed was about 20°C per hour.

The decrease of the temperature-coefficient with latitude deduced theoretically was verified experimentally. Theory and experiments agreed within ± 0.3 gammas.

C. A. HEILAND

ROBERT LEE FARIS, 1862-1932

By N. H. Heck

Captain Robert Lee Faris, Assistant Director of the United States Coast and Geodetic Survey, died suddenly at his home in Washington, D. C., on October 5, 1932. He was born at Caruthersville, Missouri, on January 13, 1868, was educated in the public schools, and received the degree of civil engineer from the University of Missouri in 1890. Before entering the service of the Coast and Geodetic Survey, he completed a year's work as assistant engineer with the Corps of Engineers, U. S. Army, on the survey of the Missouri River. During his service in the Coast and Geodetic Survey, extending over a period of more than forty years, he became thoroughly familiar with all the activities of that bureau, both through extended experience in the field and various administrative assignments in the office. He was particularly interested in terrestrial magnetism, to which he was introduced early in his career.

In the period 1893-1895 he was a member of a party engaged on the extension of the transcontinental triangulation along the 39th parallel across the Rocky Mountains. The stations were on high mountain peaks, difficult of access, and more than one month was spent at each in the measurement of horizontal and vertical angles, latitude, azimuth and terrestrial magnetism. He made many magnetic observations at places which have never since been revisited. He also determined instrumental constants between seasons.

In 1896 he made magnetic observations from Kentucky to Montana, and also at Albany and Montreal, in connection with the determination of difference of longitude of these places.

For most of the following ten years Captain Faris was engaged in hydrographic work. He was in command of the Steamer *Blake* when it was selected by Dr. Louis A. Bauer, Inspector of Magnetic Work, as the most suitable vessel of the bureau on which to test the practicability of making magnetic observations at sea. He installed a stand for the Lloyd-Creak dip circle and shared with Dr. Bauer the preliminary observations on a cruise from Norfolk, Va., to Puerto Rico, in January, 1903. In spite of the large amount of magnetic material on the *Blake*, it was found that by swinging ship to eliminate deviations, valuable data could be obtained. Accordingly it was decided to continue the work on this and other vessels of the bureau. Captain Faris carried on work energetically on the *Blake* during 1903-1904 and on the *Explorer* during 1905-1906, securing results in surveys on the coasts of Maine and Puerto Rico and en route from these places to ports in Chesapeake Bay where the vessels were repaired.

The success of this work on the vessels of the Coast and Geodetic Survey led directly to the inauguration of the ocean magnetic survey of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

With this background of field experience the selection of Captain Faris in 1906 to succeed Dr. Bauer as Inspector of Magnetic Work and

Chief of the Division of Terrestrial Magnetism was appropriate when the latter resigned to become head of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The assignment proved congenial and he continued his interest after transfer to other duties in 1914.

Under his direction notable progress was made in the work of the division. A new magnetic observatory was established at Tucson, Ariz., to give better distribution than was afforded by the temporary observatory at Baldwin, Kans. Suitable buildings were erected at Vieques, Puerto Rico, to take the place of a previous rather unsatisfactory installation in an old fort. Gaps in the magnetic survey of the United States were filled in rapidly, a regular program of repeat observations was carried on and a magnetic survey of the Philippine Islands was made. Special tabulating machines were developed to facilitate the preparation of observatory results for publication.

Captain Faris took an active part in the investigations carried on in the division and published numerous articles, among which may be mentioned:

Times of abruptly beginning magnetic disturbances as recorded at the Coast and Geodetic Survey magnetic observatories. Terr. Mag., **15**, 93-105 (1910).

On precursors of magnetic storms. Terr. Mag., **15**, 209-210 (1910).

The peculiar magnetic disturbances of December 28-31, 1908. Terr. Mag., **26**, 13-24 (1911).

On time scalings of magnetograms. Terr. Mag., **16**, 109-112 (1911).

A new type of compass declinometer. Terr. Mag., **17**, 109-114 (1912).

Captain Faris took an active part in a number of scientific societies, among which may be mentioned: American Association for the Advancement of Science, Washington Academy of Sciences, Philosophical Society of Washington (President 1921), Washington Society of Engineers (President 1921), American Society of Civil Engineers, American Astronomical Society, American Geophysical Union, Society of American Military Engineers, Geological Society of Washington, and International Association of Navigation Congresses. He was also a member of the Mississippi River Commission from 1919 until his death, in view of his intimate knowledge of that area, and of the Committee on Navigation and Nautical Instruments of the National Research Council

An earnest scholar, untiring worker, quick thinker, and endowed with a clear vision and remarkable memory, he possessed the basic qualities of the successful engineer and administrator. He enjoyed his work and inspired respect and loyalty in others. His broad knowledge and sound judgment in all scientific matters pertaining to the activities of the Coast and Geodetic Survey, combined with a kindly spirit, enabled him to render effective assistance to all who sought his counsel. He was an excellent writer himself and a helpful critic of the work of others.

After leaving the Division of Terrestrial Magnetism in 1914, to become shortly afterwards assistant director of the Survey, he retained his interest in the solution of the broad problems of terrestrial magnetism, and frequently expressed the view that many lifetimes will pass before a satisfactory solution of all the problems can be found.

RICARDO CIRERA, S. J.

REVEREND RICARDO CIRERA, S. J.

By Luis Rodés, S. J.

Rev. Ricardo Cirera, S. J., founder and first director of the Observatorio del Ebro, died at Barcelona, August 3, 1932, at the age of 66 years. He was born in Os de Balaguer (Lérida) July 16, 1864, and entered, while still very young, the Company of Jesus, of which he was a member for 52 years. The studies required by the Order were completed by him with signal success owing to his powers of clear thinking and his intense application.

Before terminating his ecclesiastical studies he was sent to the Philippines to collaborate with Father Federico Faura in directing the Manila Observatory, with the hope on the part of his superiors, that one day he would be able to replace Father Faura and take upon himself the responsibilties of the directorship. He embarked at Barcelona July 27, 1888 and reached Manila August 28, but he was able to remain only a few weeks with Father Faura who on account of his health, was obliged to leave for Spain the middle of the following month. On his arrival at the Observatory, the young student, at the time 24 years of age, assumed charge of the Magnetic Section initiated by his confrère, Father Martín Juan, and added to the absolute observations already being made by the latter, the continuous registration of the magnetic variations in a separate building constructed for the purpose where all the instruments were in normal operation on January 1, 1890.

Father Cirera remained at the Manila Observatory for six years leaving as the fruit of his scientific activity an interesting memoir "El magnetismo terrestre en Filipinas" (Manila, Tipo-Litografía de Chofré y Comp.ª, 1893) which contains an exposition of the first results obtained and the reproduction of a large number of curves relating to the diurnal, annual, and secular variations at Manila and at different stations in the Archipelago.

It was during those years of activity in the Magnetic Section that Father Cirera became greatly interested in the then nascent studies of cosmical physics and the laws governing the influence of solar activity on our planet as manifested by polar aurorae and electromagnetic storms. From this interest and the desire to collaborate in the elucidation of these very important phenomena were due the conception and realization of the vast and well-matured plan to which the Observatorio del Ebro owes its existence. In this Observatory, solar, magnetic, terrestrial-electric, seismic, and meteorological phenomena were to be registered concurrently for the first time. In its foundation, which was undertaken only after extensive study of the best observatories in Europe and America, Father Cirera was obliged to overcome difficulties of an economic and moral nature which would have discouraged one not possessing the will-power and tenacity of purpose which characterized him.

His work gave a great impetus to science in his own country, and particularly to seismology and electromagnetism which, from the date of the founding of the Observatorio del Ebro, entered upon a new phase of life and activity.

To the encouragement and diffusion of science, he contributed especially by founding the review *Ibérica* which he conducted personally from 1914 to 1917. He was a member of important national and foreign

scientific societies and was decorated by the Government with the Grand Cross of Alfonso XII in recognition of his many and fruitful studies.

He was director of the Observatorio del Ebro from 1904 to 1919 and in 1930 he had the great satisfaction of being present at the celebration of the twenty-fifth anniversary of this Observatory and of seeing how his work to which he had devoted so many wakeful nights, was continuing its development for the advantage of science, faithful to the program as outlined by its founder.

REVIEWS AND ABSTRACTS

(See also pages 430, 474, and 478)

Gutenberg, B.: *Handbuch der Geophysik.* Bd. 4 (Erdbeben), Lief. 3, 1932 (688-1005 mit 113 Abb.); Bd. 9 (Physik der Atmosphäre II) Lief. 1, 1932 (v+117 mit 73 Abb.). Berlin, Verlag von Gebrüder Borntraeger, 27 cm.

Two additional sections of the comprehensive Handbook of Geophysics, edited by B. Gutenberg have recently made their appearance. The first, by A. Sieberg, constitutes the third section of Vol. 4, and is devoted to the geography of earthquakes. Investigation of the geographical distribution of earthquake-activity should furnish useful information on the following points: Earthquake-regions and their exact boundaries, particularly the zones which, in the course of history have been especially subject to seismic disturbances and which presumably may be susceptible to future visitations; the character of activity and geological nature of disturbance-areas; regional relations of foci to one another and to general tectonics; and the frequency of earthquakes. Such information is held to be of value in the practical appraisal of theoretical earthquake-investigations and in connection with the economic aspects of possibly lessening or avoiding injurious earthquake-effects through preventive measures; it should also assist geologists in the elucidation of tectonic problems, such as for example, those pertaining to the structure of the Earth's crust and its mobility in regions not sufficiently known geologically, or in such areas as underlie the oceans and are thus difficult of access. With these objects in view, the author discusses in succession the various regions of the Earth, particularly from the geologist's standpoint, and to each discussion is appended a list of all the important earthquakes of record, together with dates of occurrence and pertinent remarks regarding locality affected, severity, etc. Figures of various areas showing earthquake activity are scattered through the text.

The second section forms the first part of Vol. 9, which is concerned with the physics of the atmosphere. The first two divisions, by B. Gutenberg, pertain to the structure of the atmosphere and the propagation of sound in the atmosphere, respectively. The portion of the former dealing with the natural phenomena in the stratosphere (twilight phenomena, zodiacal light, conducting layers in the upper atmosphere, aurora, etc.) are of especial interest to readers of the Journal. These subjects are, however, all treated in a summary manner, the author contenting himself with brief statements of those features which pertain specifically to the Earth's atmosphere and referring the reader to the more detailed discussions in other sections of the work. Thus the consideration of the zodiacal light is confined to a brief summary of F. Schmid's theory, cosmical theories being dealt with in Vol. 1. In like manner only those facts regarding polar lights which have special bearing on the structure of the atmosphere are set forth, the reader being referred for detailed information on the aurora to the relevant portion of Vol. 5, the publication of which is announced for some indefinite future time. The last chapters, by J. Tichanowski and R. Mugge, contain an exposition of our present knowledge regarding the temperature-conditions in the stratosphere.

H. D. Harradon.

PROVISIONAL SUNSPOT-NUMBERS FOR SEPTEMBER, OCTOBER, AND NOVEMBER, 1932

(Dependent alone on observations at Zürich Observatory and its station at Arosa)

Day	Sep.	Oct.	Nov.	Day	Sep.	Oct.	Nov.
1	7	7	7	17	0	8	*M*14[c]
2	7	7	10	18	0	15[d]	24
3	7	7	13	19	8	21	27
4	0	0	12	20	0	29	31
5	0	0	0	21	19	20	25
6	0	8	0	22	8	19	..
7	0	7	0	23	0	20	[b] 0
8	0	0	0	24	8	12[a]	..
9	0	0	0	25	8	11	..
10	0	0	7	26	0	10	0
11	0	0	9	27		8	0
12	14	7	9	28	8	8	..[d]
13	7	8	9	29	8	7	8
14	0	7	10	30	7	..	12
15	0	8	10	31		7	
16	0	8	0				
				Means...	4.0	9.0	9.1
				No. days.	30	30	26

Mean for quarter July to September, 1932: 6.7 (89 days).

[a]Passage of an average-sized group through the central meridian.
[b]Passage of a larger group through the central meridian.
[c]New formation of a large or average-sized center of activity; *E*, on the eastern part of the Sun's disc; *W*, on the western part; *M*, in the central zone.
[d]Entrance of a large or average-sized center of activity on the east limb.

Zürich, Switzerland W. Brunner

INFLUENCE OF LOUIS A. BAUER ON KNOWLEDGE OF TERRESTRIAL MAGNETISM THROUGHOUT THE UNITED STATES

With reference to the last publication listed under section 2 of the article "Principal published papers of Louis A. Bauer" on page 222 of the September 1932 number of the Journal, further comment may be made. The publication "Principal facts of the Earth's magnetism" was remarkable for being in constant demand on the part of the public from 1902 to 1925. By 1925 the advances in terrestrial magnetism had become so great that a new publication along the same lines was necessary and this was done by Daniel L. Hazard. The revised publication, which owes a great deal of its material to the earlier publication, is still in steady demand. Accordingly, Bauer may be credited with important influence on the knowledge of the subject of terrestrial magnetism throughout the United States of many persons who would not otherwise have been reached.

N. H. Heck, *Chief, Division of Terrestrial Magnetism and Seismology*

Coast and Geodetic Survey,
Washington, D. C.

AMERICAN *URSI* BROADCASTS OF COSMIC DATA[1]

The data for terrestrial magnetism, sunspots, and aurora are the same as given in previous tables.

The first three columns of the Table give (1) the magnetic character according to the scale 0-2 of the International Commission of Terrestrial Magnetism and Electricity, (2) the type featuring the day other than normal by letters *b*, *p*, *o*, and *i* for days marked by bay, rapid pulsations, long-period oscillations, and irregular oscillations, respectively, and (3) the hour and minute of Greenwich mean time marking the beginning of a storm, the end of the storm being indicated in the footnote to the Table. The next two columns give the data relating to sunspots: (1) the number of groups of spots and (2) the total number of spots. It is to be noted that sunspot-numbers such as those from Zürich can

Summary American URSI daily broadcasts of

Date	August*														September*				
	Magnetism			Sun-spot		Aurora									Magnetism			Sun-spot	
	Char.	Type	G. M. T. begin. distur.	Groups	No.	Char.	Duration	Cloudiness	Form: without rays	Form: with rays	Area covered	Av. altitude	Position	G.M.T. greatest distur.	Char.	Type	G. M. T. begin. distur.	Groups	No.
			h m				hrs					°		h			h m		
1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	1	1
2	1	*i*	...	1	1	...	...	...	...	...	...	...	...	...	0	...	...	1	1
3	2	*o*	...	1	1	...	...	...	...	...	...	...	...	...	0	...	...	0	0
4	1	*i*	...	1	1	...	...	...	...	...	...	...	...	...	0	...	...	0	0
5	1	*i*	...	1	1	...	...	...	...	...	...	...	...	...	0	...	...	0	0
6	0	...	...	1	1	...	...	...	...	...	...	...	...	...	1	*i*	2 22	0	0
7	0	...	...	1	1	...	...	...	...	...	...	...	...	...	1	*o*	21 ...	0	0
8	0	...	...	1	1	...	...	...	...	...	...	...	...	...	1	*o*	18 ...	0	0
9	0	...	...	0	0	1	1	1	*PA*	*D*	0.2	60	NW-NE-E	10	1	*o*	...	0	0
10	0	...	...	1	2	9	...	9	...	...	...	...	...	...	0	...	...	0	0
11	0	...	22 10	1	2	9	...	9	...	...	...	...	...	...	0	...	...	0	0
12	1	*i*	...	0	0	9	...	10	...	...	...	...	...	...	0	...	...	1	1
13	1	*i*	...	...	...	0	...	7	...	...	...	...	...	...	0	...	...	0	0
14	1	*b*	6 ...	0	0	9	...	9	...	...	...	...	...	...	0	...	...	0	0
15	0	...	...	0	0	9	...	9	...	...	...	...	...	...	0	...	...	0	0
16	0	...	...	0	0	9	...	9	...	...	...	...	...	...	0	...	...	0	0
17	0	...	...	0	0	9	...	9	...	...	...	...	...	...	0	...	...	0	0
18	0	...	...	0	0	0	...	0	...	...	...	...	...	...	0	...	...	0	0
19	0	...	...	0	0	1	1	9	HA	...	0.2	40	NW-NE-E	9	1	*b*	9 30	0	0
20	0	...	...	...	...	1	1	8	HB	...	0.2	20	NW-NE-E	11	1	*o*	...	0	0
21	0	...	...	0	0	9	...	10	...	...	...	...	...	...	0	...	...	2	5
22	0	...	...	0	0	1	1	9	HB	...	0.2	40	NW-NE-E	11	0	...	...	2	2
23	1	*b*	5 15	1	1	1	1	8	DS	...	0.2	20	N-NE	9	1	*b*	8 30***	0	0
24	0	...	...	2	4	9	...	10	...	...	...	...	...	...	1	*i*	...	0	0
25	0	...	...	2	11	3	2	0	PA	R	0.2	50	N-NE-E	9	2	*i*	...	0	0
26	0	...	...	...	...	1	1	10	HA	...	0.2	20	N-NE-E	9	1	*i*	18 40	0	0
27	1	*b*	7 40**	2	11	5	4	2	HV	RB	0.6	90	N-NE-SE	8	1	*p*	...	1	4
28	2	*o*	...	2	5	3	4	8	HV	...	0.4	45	NW-N-E	8	0	...	...	1	2
29	2	*i*	...	2	2	1	2	9	HA	...	0.2	40	NW-N-NE	8	0	*b*	1 ...	1	3
30	1	*i*	...	1	1	1	1	9	HV	...	0.2	30	NW-N-NE	9	0	...	...	1	1
31	1	*i*	...	1	1	9	...	10											
Mean	0.5	...	...	0.8	1.7	1.5	1.7	8	...	...	...	...	...	9	0.4	...	...	0.4	0.7

Greenwich mean time for endings of storms: $8^h\ 30^m$, Aug. 13; $6^h\ 15^m$, Aug. 23; $9^h\ 00^m$, Aug. 27; 23^h, 10; $10^h\ 30^m$, Oct. 23; 12^h, Oct. 30.

*Reports of solar constant from Chile still unsatisfactory.

**Another disturbance began at $20^h\ 20^m$ on Aug. 27.

***Another disturbance began at $15^h\ 35^m$ on Sep. 23.

be obtained from the number of groups and spots given in the Table by the formula $N=k\ (10g+s)$, where k for Mount Wilson is about 0.77.

Under the general heading of aurora in the table, the first column gives the character of the day: 0 indicates no aurora; 1, faint; 3, moderate; 5, strong; 7, brilliant; and 9, no observation or no observations possible on account of cloudiness. The second column gives the number of hours during which aurora was present. The third column indicates the amount of sky covered by cloud on a scale of 0-10, where 0 means cloudless, and 10 completely overcast.

Because of the long daylight the auroral observations at Fairbanks, Alaska, were discontinued May 16 and resumed on August 9.

[1]For previous announcements see Terr. Mag., **35**, 184-185 and 252-253 (1930); **36**, 54, 141, 258-259, and 358-360 (1931); **37**, 85-89, 189-192, and 409-411 (1932).

cosmic data, August to October 1932

September*									October*															
Aurora									Magnetism				Sunspot		Aurora									Date
Char	Duration	Cloudiness	Form without rays	Form with rays	Area covered	Av. altitude	Position	G.M.T. greatest distur.	Char	Type	G. M. T. begin. distur.		Groups	No.	Char.	Duration	Cloudiness	Form without rays	Form with rays	Area covered	Av. altitude	Position	G.M.T. greatest distur.	
	hrs					°		h			h	m				hrs					°		h	
3	2	1	HA	RA	0.4	30	NW-NE-E	7	0	..	..	....	1	1	3	5	5	HV	RV	0.6	35	NW-NE-E	10	1
1	1	2	DS	R	0.4	20	NW-NE-E	7	0	..	..	....	0	0	5	7	3	HV	RV	0.6	75	W-N-E	10	2
1	3	1	HA	.....	0.2	15	N-NE-E	9	0	..	..	....	2	2	9	...	10	.....	.....	...	...	....	....	3
1	1	3	HA	.....	0.2	20	NW-N-E	9	0	..	..	....	0	0	9	...	10	.....	.....	...	...	....	....	4
3	4	1	HA	R	0.4	45	W-N-E	12	0	..	..	....	1	2	9	...	10	.....	.....	...	...	....	....	5
5	7	3	HV	RV	0.8	90	NW-NE-SE	13	0	..	..	....	1	7	0	...	3	.....	.....	...	...	....	....	6
1	3	4	HV	R	0.6	35	W-N-E	10	0	..	..	....	1	7	1	1	9	HA	.....	0.2	12	NW-N-NE	11	7
3	6	2	HA	RV	0.6	65	NW-N-E	8	0	..	..	....	0	0	9	...	10	.....	.....	...	...	....	....	8
3	6	1	HA	RA	0.4	30	NW-N-E	11	0	..	15	....	0	0	1	6	3	HA	.....	0.2	18	NW-N-E	11	9
1	1	5	DS	.....	0.2	20	NE	9	1	p	..	....	0	0	3	8	4	HV	.....	0.4	30	NW-N-E	11	10
1	1	0	DS	R	0.4	18	NW-N-NE	10	0	..	..	....	0	0	1	1	6	HA	.....	0.2	15	NW-N-NE	10	11
1	2	0	HA	.....	0.2	15	NW-N-E	11	0	..	..	....	1	2	1	3	0	HA	.....	0.2	15	NW-N-NE	11	12
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	2	1	1	3	HA	.....	0.2	20	NW-N-NE	10	13
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	1	1	1	0	HA	.....	0.2	15	N-NE	10	14
9	...	10	.....	.....	...	...	....	...	1	o	2	40	1	1	1	1	0	.....	RB	0.2	30	N-NE	14	15
9	...	10	.....	.....	...	...	....	...	1	i	..	....	2	3	9	...	10	.....	.....	...	...	....	....	16
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	1	1	2	2	HA	RB	0.6	45	NW-N-E	9	17
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	1	9	...	10	.....	.....	...	...	....	....	18
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	2	1	2	5	HA	.....	0.2	15	NW-N-NE	6	19
9	...	10	.....	.....	...	...	....	...	0	..	..	....	2	5	9	...	...	.....	.....	...	...	....	....	20
9	...	10	.....	.....	...	...	....	...	1	i	..	....	1	6	1	4	8	HA	RA	0.4	60	NW-NE-E	11	21
3	7	1	HV	RA	0.4	75	NW-NE-SE	10	0	..	..	....	2	6	1	1	7	G	.....	0.2	15	NW-N	11	22
2	6	5	HV	RV	0.8	90	W-NE-SE	11	1	b	9	00	2	6	3	4	5	HV	RV	0.6	90	W-N-E	9	23
3	7	1	HV	RV	0.6	70	NW-NE-SE	8	0	..	..	....	...	...	1	2	7	G	.....	0.2	30	NW-N-NE	14	24
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	5	9	...	10	.....	.....	...	...	....	....	25
1	3	5	HV	RV	0.2	20	NW-N-E	11	0	..	..	....	1	3	1	1	5	HA	.....	0.2	70	NW-NE-E	13	26
1	4	5	HV	RB	0.4	30	NW-N-E	11	0	..	..	....	1	1	3	3	7	HA	.....	0.4	65	NW-NE-SE	11	27
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	1	1	3	5	PA	.....	0.4	20	W-N-NE	10	28
9	...	10	.....	.....	...	...	....	...	0	..	..	....	1	1	0	...	4	.....	.....	...	...	....	....	29
5	8	2	HV	RV	0.4	50	NW-NE-SE	8	1	o	5	30	2	3	3	8	8	HV	.....	0.4	30	NW-N-E	11	30
...	...	...	.....	.....	...	...	....	...	0	..	..	....	1	1	1	3	8	HA	.....	0.2	55	NW-N-E	14	31
2.2	4.0	5	.....	.....	...	...	....	10	0.2	..	..	....	1.0	2.3	1.7	3.2	6	.....	.....	...	...	....	11	Mean

Sep. 6; 8h, Sep. 8; 6h, Sep. 9; 11h 00m, Sep. 19; 9h, Sep. 20; 10h 00m. Sep. 23; 12h. Sep. 26; 3h 00m, Sep. 27; 7h, Oct.

Kennelly-Heaviside Layer heights, Washington, D. C.

Date	Frequency	Nearest hour G.M.T.	Height	Date	Frequency	Nearest hour G.M.T.	Height
1932	*kc/sec*	*h*	*km*	*1932*	*kc/sec*	*h*	*km*
Aug. 3	5,000	20	No value obtained	Sep. 14	5,000	20	360
" "	4,500	20	270	" "	4,500	20	280
" "	4,000	20	620, 800	" "	4,000	21	240, 360
" "	3,500	20	110	" "	3,500	21	260, 310
" "	3,000	20	110	" "	3,000	21	230
" 10	6,000	19	No value obtained	" "	2,400	21	220
" "	5,800	19	430	" "	2,300	21	290
" "	5,500	19	390	" "	2,200	21	110
" "	5,000	19	340	" 15	2,050	5	310*
" "	4,500	20	100, 530	" "	4,100	5	570*
" "	4,000	20	290	" "	8,000	5	No value obtained*
" "	3,500	20	100, 220	" 21	2,900	17	120
" "	3,100	20	100	" "	3,000	17	140
" 15	6,200	19	No value obtained	" "	3,100	17	110, 230
" "	6,100	19	550	" "	3,200	17	110, 220
" "	6,000	19	420	" "	3,000	18	150
" "	5,800	19	380	" "	3,500	18	220
" "	5,400	19	380	" 24	4,000	18	220, 330, 390
" "	5,000	19	130, 300	" "	4,500	19	250, 320
" "	4,600	19	150, 240	" "	5,000	19	310
" "	4,400	19	140, 320	" "	5,500	19	320
" "	4,200	19	100, 380	" "	5,950	19	530
" "	4,000	19	100, 290	" "	6,250	19	No value obtained
" "	3,800	19	100, 230	" 28	6,000	20	" " "
" "	3,600	19	100, 250	" "	5,800	20	800
" "	3,400	19	100	" "	5,500	20	430
" "	3,000	19	100	" "	5,000	20	350
" 26	5,500	21	No value obtained	" "	4,500	20	310
" "	5,000	21	280	" "	4,200	20	260, 330
" "	4,100	21	250	" "	4,000	20	250, 330
" "	3,300	21	130, 240	" "	3,500	20	120, 240
" "	3,000	21	110	" "	3,000	20	120, 230
Sep. 1	6,000	19	No value obtained	" "	2,700	20	110, 230
" "	5,500	19	360	" "	2,500	20	110
" "	5,000	19	320	Oct. 5	6,600	19	No value obtained
" "	4,500	19	300	" "	6,500	19	800
" "	4,200	19	220, 350	" "	6,000	19	380
" "	3,300	19	210	" "	5,500	19	320
" "	3,100	19	120	" "	5,000	19	280
" 7	6,500	19	No value obtained	" "	4,500	20	280
" "	6,000	19	760	" "	4,200	20	260, 280
" "	5,500	19	350	" "	4,000	20	240, 280
" "	5,000	19	340	" "	3,500	20	260
" "	4,500	19	250, 310	" "	3,000	20	230
" "	4,000	19	240, 320	" "	2,900	20	230
" "	3,500	19	220	" "	2,700	20	130
" "	3,000	19	120	" "	2,500	20	120
" "	2,500	19	110	" 12	8,000	17	720*
" "	2,000	19	110	" "	4,100	17	120,* 280*
" 14	2,050	17	110*	" "	2,050	17	110*
" "	4,100	17	230,* 330*	" "	7,200	19	740
" "	8,000	17	No value obtained	" "	7,100	19	380
" "	6,000	20	" " "	" "	7,000	19	370
" "	5,500	20	810	" "	6,500	19	300
" "	5,300	20	380	" "	5,950	19	290

*Polar-Year values.

Kennelly-Heaviside Layer heights, Washington, D. C.—Continued

Date	Frequency	Nearest hour G.M.T.	Height	Date	Frequency	Nearest hour G.M.T.	Heigth
1932	*kc/sec*	*h*	*km*	*1932*	*kc/sec*	*h*	*km*
Oct. 12	5,500	19	270	Oct. 19	2,800	20	100
" "	4,950	19	270	" 26	9,500	20	No value obtai
" "	4,500	19	260	" "	9,000	20	790
" "	4,200	19	250, 280	" "	8,500	20	750
" "	4,000	19	230, 280	" "	8,000	20	720
" "	3,500	19	230	" "	7,500	20	630
" "	3,000	20	170, 290	" "	7,000	20	370
" "	2,500	20	120	" "	6,500	20	300
" 19	5,950	20	250	" "	6,000	20	270
" "	5,500	20	240	" "	5,500	20	260
" "	5,000	20	250	" "	5,000	20	260
" "	4,500	20	250	" "	4,500	20	250
" "	4,200	20	250	" "	4,000	20	250
" "	4,000	20	140, 250	" "	3,500	20	130, 260
" "	3,500	20	110, 240	" "	3,000	20	100, 230
" "	3,200	20	110, 230	" "	2,500	20	110
" "	3,000	20	100, 230				

*Polar-Year values.

The table of Kennelly-Heaviside Layer heights is self-explanatory.

Department of Terrestrial Magnetism,
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Washington, D. C.

Katharine B. Clarke

JAPANESE URSIGRAM

In cooperation with the Naval Experimental and Research Establishment, the Central Meteorological Observatory of Japan, the Tokyo Astronomical Observatory, and the Department of Communications, the Japanese National Committee of URSI has arranged to collect the data for the use of the Ursigram and broadcast it from the Tokyo Radio Station, *JAN*.

Transmission schedule of the Ursigram—The Ursigram in code described below is transmitted weekly, on Saturdays at 13^h G.M.T. on frequency 11980 kc/s beginning September 8, 1932.

Codes used—Each class of data is coded separately and preceded by an identifying word: *SOL* for sunspots, *MAG* for terrestrial magnetism, and *KHL* for Kennelly-Heaviside Layer heights. The data are grouped weekly beginning on Thursday and are expressed in a number code in groups of five. Plain English will be added when extraordinary phenomena demand it.

The code for the sunspots is composed of seven groups of five figures following the designation *SOL*. In each group the first figure indicates: 1, Sunday; 2, Monday; 3, Tuesday; 4, Wednesday; 5, Thursday; 6, Friday; and 7, Saturday. Second and third figures indicate number of groups of sunspots preceded by zero if less than ten. Fourth and fifth figures indicate total number of sunspots, preceded by zero if less than ten. Plain English descriptions of unusual solar phenomena will be added where necessary. The sunspot data are furnished by the Tokyo Astronomical Observatory.

The code for the terrestrial magnetism is composed of two groups of five figures following the designation *MAG*. First figure of the first

group indicates the place of observation, namely: 8, Kakioka, Ibaraki prefecture, Japan; longitude 140° 11′ 21″ east, latitude 36° 13′ 51″ north; height above sea-level, 28.2m. Second and third figures of the first group indicate the date on which the information commences and it is always fixed on Thursday. Fourth and fifth figures of the first group indicate the state of terrestrial magnetism on Thursday and Friday and first to fifth figures of the second group indicate those on Saturday, Sunday, Monday, Tuesday, and Wednesday, respectively. The meaning of these figures are: 0, calm; 1, rather calm; 2, slight disturbance; 3, disturbance; 4, storm of rather sudden commencement; 5, storm of sudden commencement; 6, remarkable storm of rather sudden commencement; 7, remarkable storm of sudden commencement; 8, storm of slow commencement; and 9, remarkable storm of slow commencement.

The code for the Kennelly-Heaviside Layer consists of three groups of five figures following the designation *KHL*. The first figure of the first group indicates the place of observation, namely, 7, Tokyo. The second, third, fourth, and fifth figures of the group give the observed frequency in kilocycles per second divided by 10. The first figure of the second group indicates the day of the week: 1, Sunday; 2, Monday; 3, Tuesday; 4, Wednesday; 5, Thursday; 6, Friday; and 7, Saturday. The second and third figures of this group give the nearest Greenwich mean hour; the fourth and fifth figures give the height of the first Kennelly-Heaviside *E*-layer in kilometers divided by 10. The third group indicates the height of the second layer. Figures of this group have the same meaning as in the second group except that the fourth and fifth figures indicate the height of the *F*-layer in kilometers divided by 10.

Example and translation—A typical example of an Ursigram as broadcast from the Tokyo Radio Station follows:

SOL 50102 60105 70110 10104 20102 30103 4*XXXX* *MAG* 80100 02106 *KHL* 70400 51519 51537

The translation of the above message is as follows: *Sunspots* observed at the Tokyo Astronomical Observatory were for number of groups and number of spots respectively: Thursday—1, 2; Friday—1, 5; Saturday—1, 10; Sunday—1, 4; Monday—1, 2; Tuesday—1, 3; and Wednesday—no observations. Condition of *terrestrial magnetism* observed at Kakioka was: Thursday, calm; Friday, calm; Saturday, calm; Sunday, slight disturbance; Monday, rather calm; Tuesday, calm; and Wednesday, remarkable storm of rather sudden commencement. *Kennelly-Heaviside Layer* heights observed at Tokyo for a frequency of 4000 kc/s Thursday at 15^h G.M.T. were 190 kilometers for the first layer and 370 kilometers for the second layer.

H. Nagaoka, *Chairman, National Committee on Radio Research*

National Research Council of Japan,
Tokyo, Japan

PROVISIONAL SOLAR AND MAGNETIC CHARACTER-FIGURES, MOUNT WILSON OBSERVATORY, JULY, AUGUST, AND SEPTEMBER, 1932

The only magnetic storm during the third quarter of 1932 in which the total range in H exceeded 100γ was on August 27 and 28. It was probably caused by the small active group No. 4367, which crossed the central meridian on August 25.5, G.M.T. It began August 27 at 21^h and ended the following day at about 10^h, having had a range of 137 gammas.

Day	July 1932								August 1932								September 1932							
	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.	K_2		$H\alpha B$		$H\alpha D$		No. groups	Mag'c char.
	A	B	A	B	A	B			A	B	A	B	A	B			A	B	A	B	A	B		
1	2	2	2	2	0	0	3	0	1	1	1	2	1	0	1	0.5	0	0	0	0	1	0	1	0
2	2	2	2	2	0	0	3	0	1	1	1	1	0	0	1[a]	0.5	0	0	0	0	1	0	1	0
3	2	1	2	1	0.5	0	4	0	1	1	1	1	1	0	1	0.5	0	0	0	0	1	0	0	0
4	2	1	2	1	1	1	3	0.5	1	0.5	1	0.5	0	0	1	0.5	0	0	0	0	1	1	0	0
5	1	2	2	2	1	0	3[b]	0.5	0	0	0.5	0	1	0	1	0.5	0	0	0	0	1	1	0	0
6	1	1	2	2	1	1	1[a]	0.5	0	0	0	0	1	0.5	1	0	0	0	0	0	0	0	0	1.0
7	1	2	2	2	2	1	1	0.5	0	0	0	0	0.5	0.5	1	0	0	0	0	0	0	0	0	0
8	1	1	1	1	2	0.5	1	0.5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.5
9	1	0	1	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.5
10	1	0	1	0	1	0	1	0.5	0	0	0	0	0.5	0	1	0	0	0	0	0	0	0	0	0
11	0	0	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
12	0	0	0	0	1	1	1	0.5	0	0	0	0	1	0	0	0.5	0	0	0	0	0	0	1	0
13	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
14	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
15	0	0.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	1	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
17	0.5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5
19	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
20	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
21	0.5	0.5	1	1	1	1	1	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	2	0.5
22	0.5	0.5	0.5	0	0	0	1	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	1	0	1	0.5
23	0.5	1	0.5	0.5	0	0	0	0	0	0	0	0	0	0	1	0.5	0	0.5	0	0	0	0	0	1.0
24	0	0.5	0	0	0	0	0	0	0	0.5	1	0.5	0	0	2	0	0	0.5	0	0.5	0.5	0.5	0	1.0
25	0.5	1	0	0	0	0	0	0	1	1	1	1	1	0	2[b]	0.5	0	0.5	0	0	0	0	0	1.0
26	0.5	0.5	0	0	0	0	0	0	1	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0.5
27	0.5	0.5	0	0	0	0	1	0	1	0.5	1	0.5	0	0	2	1.0	0	0	0	0	0	0	1	0
28	0.5	0.5	0.5	0	0	0	1	0	1	0.5	1	0.5	0	0.5	2	1.5	...	...	...	...	...	...	1	0
29	1	0	0.5	0	0.5	0	2	0	1	1	1	1	1	1.5	2	1.0	0	0	0	0	0	0	1	0
30	1	0.5	1	0	0	0	2	0	1	1	1	1	1	1	1	0.5	.	...	0	0	0	0	2	0
31	1	1	1	0.5	1	0	1	0.5	0	0	0	0	1	0	1	0.5								
Mean	0.8	0.7	0.9	0.6	0.6	0.3	1.1	0.2	0.3	0.3	0.4	0.3	0.4	0.1	0.8	0.3	0.0	0.1	0.0	0.0	0.3	0.1	0.4	0.3

[a]Passage of an average-sized group through the central meridian within 15° of the center of the disc.
[b]Passage of a small group through the central meridian within 15° of the center of the disc.

Carnegie Institution of Washington,
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SETH B. NICHOLSON
ELIZABETH E. STERNBERG

PRINCIPAL MAGNETIC STORMS

Sitka Magnetic Observatory

July to September, 1932[1]

(*Latitude 57° 03′.0 N.; longitude, 135° 20′.1 or 9h 01m.3 W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1932	*h m*	*d h m*	′	γ	γ
July 5	14 00	6 16 ..	100.1	636	682
July 16	5 ..	17 14 ..	65.6	641	655
Aug. 2	18 ..	5 12 ..	64.8	272	468
Aug. 27	7 47	30 18 ..	108.7	537	609
Sep 6	5 ..	6 18 ..	57.3	819	691
Sep. 24	5 ..	26 12 ..	98.3	554	452

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

There were no large magnetic storms during the third quarter of 1932.

July 5-6, 1932—This was a small storm with the greatest activity between 5^h and 10^h, July 6.

July 16-17, 1932—This was a small storm with practically no activity except from 6.5^h to 15^h, July 16.

August 2-5, 1932—This was a storm of small activity divided along a long period. There was a period of moderate activity between 6^h and 13^h, August 3. The curve is smooth from 13^h August 4 to 5^h August 5 and then there is a small activity to the finish of the storm.

August 27-30, 1932—This storm began with a sharp jog making a large bay especially in *D*. The period of greatest activity was between 1^h and 11^h, August 28. The next period of moderate activity was between 4^h and 16^h, August 29.

September 6, 1932—A fairly sharp curve marked the beginning of this storm. The noted thing about this storm is the large activity between 12^h and 15^h, September 6.

September 24-26, 1932—This is a storm of moderate activity with no period of large activity.

Franklin P. Ulrich, *Observer-in-Charge*

Cheltenham Magnetic Observatory

July to September, 1932[1]

(*Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5h 07m.4 W. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Ver. int.
1932	*h m*	*d h m*	′	γ	γ
Aug. 27	22 ..	28 12 ..	53.2	157	137

[1]Communicated by R. S. Patton, Director, United States Coast and Geodetic Survey.

The disturbance of which this storm is the principal portion, began about 9^h August 27, and continued to about 17^h August 30. The storm itself consisted mainly of a series of large undulations, without rapid or sudden movements.

GEO. HARTNELL, *Observer-in-Charge*

HUANCAYO MAGNETIC OBSERVATORY JULY TO SEPTEMBER, 1932

(*Latitude 12° 02′.7 S.; longitude 75° 20′.4 or 5^h 01^m W. of Gr.*)

July 16, 1932—An unusual feature marked the variations of the elements on July 16. From 12^h to 17^h G.M.T. a considerable agitation appeared in the traces, producing a minimum in horizontal intensity at 14^h 17^m G.M.T. and completely wiping out the pronounced rise in horizontal intensity which usually occurs at this time. The value of the horizontal intensity at 14^h 17^m G.M.T. was approximately 160 gammas less than the average value for that time as obtained from the mean monthly curve. The range in horizontal intensity on this day was 117 gammas, which is somewhat less than normal. The regular variations in declination and vertical intensity were also appreciably suppressed.

PAUL G. LEDIG, *Observer-in-Charge*

WATHEROO MAGNETIC OBSERVATORY JULY TO SEPTEMBER, 1932

(*Latitude 30° 19′.1 S.; longitude 115° 52′.6 or 7^h $43^m.5$ E. of Gr.*)

There were no notable storms recorded during the third quarter of 1932.

W. C. PARKINSON, *Observer-in-Charge*

NOTES

29. *International Polar Year stations*—It is gratifying to learn from a communication of Director J. Patterson, of the Meteorological Service of Canada, dated October 21, 1932, that the work at all the Canadian Polar Year stations is well under way. At the station at Cape Hope's Advance, the full program is in operation, but few auroral observations have been possible because of cloudy weather. At Chesterfield Inlet the party has all the instruments installed including the magnetic, earth-current, meteorological, as well as kites, balloons, earth thermometers, and differential thermometers between the top of the mast and the thermometer screen. A second auroral post has been established about twenty miles from Chesterfield. A message dated October 17 indicated that the earth-current and declination results were closely related, that a declination-range of seven degrees was obtained on one of the disturbed days, and that already there were deep snow-drifts about the station. The program at Coppermine is also in full operation and the magnetic instruments at Meanook are working satisfactorily. Auroral and special cloud-observations are also being made at a selected number of stations across Canada.

A dispatch from J. M. Stagg, leader of the British Polar Year Expedition, at Fort Rae, Canada, as reported in *The Times*, states that "the first big jobs were the preparing

of huts for instrumental gear. By August 1 every instrument was functioning and the routine of observations every three hours throughout the day was instituted. Already, in July, aurora had been noticed on several evenings, and all during August there was a display every evening. Rae must be near, if not actually inside, the zone of maximum auroral frequency."

Construction work on the buildings for the College-Fairbanks station was started August 1, 1932, and despite protracted rains and some delay in the delivery of materials, the buildings were completed, with only slight departures from the plans, so that practically all the instruments could be installed during the month of September. Numerous difficulties were encountered in setting up and adjusting the magnetic variation-instruments but these were nearly overcome by October 1, when continuous records were being obtained on almost all of the installed instruments. Preliminary determinations of east magnetic declination gave the following values: 30° 22′.5 at the site of the absolute observatory, 30° 23′.9 at a point 525 feet southeast of the site, and 30° 24′.7 at a point about 550 feet northwest of the site.

C. J. McGregor, in charge of the Polar Year Station at Point Barrow, Alaska, reported November 10, 1932, that excellent progress is being made. The expedition landed in a blinding snow-storm on the afternoon of September 6 and the Weather Bureau building was near enough to completion that regular meteorological observations could be begun September 15. By November 10, 92 balloon-observations had been made. Very detailed observations of the aurora are part of the regular program. Nearly 100 star-maps on which auroral positions have been plotted had been completed and about 60 auroral photographs had been taken. Construction of the magnetic buildings was begun as soon as the Weather Bureau building was far enough advanced to provide shelter. The magnetograph was put into operation October 1 and good readings have been obtained since that date. Absolute observations are made and scale-values obtained every Monday. The successful carrying out of the heavy program at this important station will ensure a very valuable contribution to the data collected during the Polar Year.

We have learned with much pleasure from a letter received from Don Louis Cifuentes, Chief of the Spanish Commission for Polar Year work in Guinea, that an observatory for obtaining meteorological and magnetic observations has been established at Moka, Fernando Póo, since August 1, 1932.

It is very gratifying to note that, in spite of the unfavorable economic conditions prevailing in Germany, it has been found possible through private initiative, to establish a German polar station. Although a great many obstacles had to be overcome in connection with this enterprise, its realization was at last made possible thanks to its organization by the Archiv für Polarforschung at Kiel, and to the equipment available from previous polar expeditions. The expedition left Copenhagen October 9, for Arsuk in southwest Greenland (latitude 61° north, longitude 48° west) under the leadership of Dr. Max Grotewahl who will carry out the magnetic and auroral observations. Dr. Kern, of Breslau-Krietern, will have charge of the meteorological work. The auroral observations will be made in cooperation with the Danish station at Julianehaab. A small equipment for collecting biological material was also included in the outfit. The station was to be established in the vicinity of the settlement of Arsuk. The magnetic and meteorological instruments were to be housed in special buildings. It was planned that the work will extend over a period of eleven months and that the party will be increased by three or four men in the spring.

We learn from the Bulletin of the Arctic Institute, Leningrad, that in accordance with an agreement with the "Notgemeinschaft der Deutschen Wissenschaft," two young German scientists, Dr. K. Wölcken of the Geophysical Institute, Göttingen, recently a member of the Wegener Expedition to Greenland, and Dr. Scholtz of the Magnetic-

Meteorological Observatory, Potsdam, will take part, during the Polar Year, in the work at the polar stations established by the Arctic Institute. Dr. Wölcken will work with the leader of the Novozemlsk Expedition, M. M. Yermolayev, on the ice-cap of Novaya Zemlya, in applying seismological methods to glaciological observations. Dr. Scholtz will be a member of the wintering party at Hooker Island, Franz Josef Land, having charge of the observations in atmospheric electricity.

The following stations will be operated by Japan during the Polar Year 1932-1933: (1) At Toyahara, a new Polar Year observatory on Saghalin in latitude 46° 58′ north, longitude 142° 44′ east, where magnetic registration will be obtained by an Eschenhagen and a special high-speed magnetograph as also records of earth-currents, potential gradient, and conductivity of the atmosphere and meteorological observations. (2) At Kakioka, the permanent observatory under the charge of Dr. S. Imamiti, will record regular and high-speed registration of magnetic elements, of earth-currents, and of atmospheric electricity. (3) At Mount Fuji at (*a*) a new Polar Year observatory on the summit (altitude 3,750 meters) where solar and meteorological observations will be made and at (*b*) a base-station at Hunatu on the shore of Lake Kawaguti. (4) At Miho to secure aerological observations with airplanes. (5) At Maneda, Misima, Osaka, and Hukuoka for pilot-balloon observations on international days. (6) At Haneda where photogrammetric observations of clouds are to made when weather permits.

Work was begun at the following new Polar Year stations: (1) Italian station at Mogadiscio, middle of July; (2) magnetic station at Cape Town, July 25; (3) Swedish station at Spitzbérgen, before August 20; (4) Islandic magnetic station at Reykjavik, August 22.

30. *German Geophysical Society*—The tenth meeting of the German Geophysical Society took place in Leipzig, October 4 to 10, 1932. In the opening session Fr. Linke presented a report on the "Influence of geophysical phenomena on health." He dealt chiefly with the effects of weather-conditions, the different kinds of radiations, and the still mysterious radiations above subterranean water-veins. Dr. Lehmann gave a report on "Potential gradient and conductivity over water-veins, as a contribution to the question of the divining-rod." K. Wegener reported on the results of his brother's expedition over the inland ice of Greenland, of the *Nautilus* expedition, including Dr. Villinger's gravity-determinations, and of the *Zeppelin* expedition of the Aeroarctic. The preliminary figure for the depth of the ice in Greenland, 2,700 meters has been reduced by later critical computations to 1,800 to 2,000 meters. F. A. Vening-Meinesz also gave an account of his various submarine trips for determining gravity. G. Angenheister reported on the equipment and work of the Seismological Institute in Leningrad and A. Defant summarized the results obtained at the anchor-stations of the *Meteor*-Expedition.

Ad. Schmidt showed in how far the terrestrial-magnetic secular variation can be explained by a uniformly rotating magnetized earth-body. Material is available merely for the variation in direction of the Earth's field, as the series of intensity-observations is too short. It is found that the amplitude depends upon the geographical latitude, the phase on the longitude. The axis of rotation of the inner sphere passes through 0° longitude and 30° north latitude, the rotation is clockwise, and the moment of the rotating core would be a fifth of the moment of the Earth. This discussion applies to European stations, not elsewhere. It is most essential to continue the investigation of the secular variation of the great regional anomalies and especially to verify the facts by repeated determinations. T. Schlomka developed further his general theory of gravity and magnetism. A Nippoldt first gave a report on German work during the Polar Year and then spoke on the subject of the general noise in the atmosphere.

A number of papers were also given dealing with instrumental questions. Among these may be mentioned the following: A description of an oscillation-counter for physi-

cal and terrestrial-magnetic purposes which permits a high degree of precision, by G. Fanselau; demonstration of a field-balance for vertical intensity which shows very small temperature effects, by J. B. Ostermeier. In connection with the meeting, the Askania-Werke in Friedenau, had arranged an exhibit of its geophysical instruments.

The meeting closed with a visit to the new Geophysical Observatory on the Colmberg, in connection with the formal presentation of the keys to its Director, Prof. L. Weickmann, of Leipzig.

31. *Magnetic field-work, United States Coast and Geodetic Survey*—Continuing the five-year program of magnetic repeat-observations for the United States, R. G. Ambrose is to begin his next field-season about January 5, 1933. From Richmond, Virginia, he will go southward to the vicinity of Atlanta, Georgia. Near that point he will continue the transferring of old repeat-stations to triangulation-stations of the system of first-order arcs of this country. He will follow along approximately 1600 miles of first-order triangulation from Virginia westward to the Louisiana-Texas boundary, thence along the 94th meridian between Fort Smith, Arkansas, and Beaumont, Texas, continuing from Beaumont, Texas, to Corpus Christi, Texas, and from Amarillo, Texas, to the Mexican boundary. He will then occupy old repeat-stations westward to Tucson, Arizona, where comparison-observations will be made with the instruments of the magnetic observatory located there. All travel will be by automobile truck and trailer. Mr. Ambrose will be accompanied by an assistant observer to expedite the work and to facilitate the transferring of old stations to triangulation-stations. Two complete sets of instruments and equipment will be carried.

32. *San Juan Magnetic Observatory*—For the second time in four years the variation and absolute buildings of the San Juan Magnetic Observatory (Puerto Rico) were damaged by hurricanes September 27, 1932. These are being rebuilt by enclosing the present buildings in a concrete shell reinforced by non-magnetic trolley wire in the hopes that they will be able to survive later hurricanes without damage.

33. *Cheltenham Magnetic Observatory*—The buildings at the Cheltenham Magnetic Observatory (Maryland, United States) used for absolute observations, comparison observations, tests and office, one of which is more than 30 years old, are being remodeled to meet present day needs in all these fields. This is especially important because of the designation some years ago of this Observatory, along with the Standardizing Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, as the standardizing observatory of the United States for international comparison of instruments.

34. *Annual Exhibition of the Carnegie Institution of Washington*—The annual exhibition of results of research activities by the Carnegie Institution of Washington, was presented at the Institution's Administration Building in Washington, December 10, 11, and 12, 1932. The eleven exhibits represented a wide range of scientific investigations of which the following bore on recent work in cosmical and terrestrial physics: "The search for an understanding of magnetism" through the study of magnetic and electric forces inside the atom, by M. A. Tuve of the Department of Terrestrial Magnetism; "The velocity of light," dealing with recent results obtained by the staff of the Mount Wilson Observatory, by W. S. Adams, and "The Sun," a key to phenomena on Earth, in stars, and atoms, by Seth B. Nicholson, of the same Observatory; "Climatological research" as revealed by the variation in width of tree-rings, by A. E. Douglass of the University of Arizona; "Seismological research," a study of location of earthquakes in California, by H. O. Wood, Research Associate in Seismology; "Volcanic

gases," with special reference to the constructive rôle of volcanic activity, by E. G. Zeiss, of the Geophysical Laboratory, Washington, D. C. Public lectures were given in the evenings explanatory of the exhibits.

35. *Cosmic-ray symposium*—In affiliation with Section B (Physics) of the American Association for the Advancement of Science, there was held December 30, 1932, at Atlantic City, New Jersey, a symposium of invited papers on cosmic rays. The speakers at this symposium were Dr. Gordon L. Locher of the Bartol Research Foundation on "Expansion-chamber data on cosmic-ray ionization"; Prof. R. A. Millikan and Dr. H. Victor Neher of the California Institute of Technology on "New technique in the cosmic-ray field and some of the results obtained from it"; and Prof. Arthur H. Compton of the University of Chicago on "Some evidence regarding the nature of cosmic rays."

36. *Erratum*—In note 26, on page 290 of the September 1932 number of the JOURNAL, the station occupied by Prof. Poulter during the eclipse of August 31, 1932, should be given as Birch Island, Maine, which is about six-tenths of a mile from the New Hampshire state line.

37. *Personalia*—The Copley Medal has been awarded by the President of the Council of the Royal Society of London, to Dr. *G. E. Hale*, for his distinguished work on the magnetic field of the Sun.

The Prussian Academy of Sciences has bestowed upon Dr. *Hugo Eckener*, President of the Luftschiffbau Zeppelin Gesellschaft in Friedrichafen, the Gold Leibnitz-Medal in recognition of his contributions to science, particularly to meteorology, through the numerous and extensive flights of the *Graf Zeppelin*.

Geoffrey Builder, formerly a member of the staff of the Watheroo Magnetic Observatory, is engaged in investigatory work on the ionosphere at the Auroral Observatory, Tromsö, Norway, as a part of the Polar-Year program of the Radio Research Board of England.

The appointment this September of Dr. *Jerry Hall Service* as assistant professor of mathematics and physics at the Michigan College of Mining and Technology, Houghton, marks a further expansion of the geophysical research program conducted by that institution under the direction of Professor *James Fisher*. Dr. Service, who will combine instructional and research duties, has been connected with the United States Coast and Geodetic Survey, and comes to Tech from the headship of the mathematics and physics department of Henderson State College, Arkadelphia, Arkansas.

We regret to record the death in October at Paris, of *Father Louis Froc*, who was director of the Zi-Ka-Wei Observatory, Shanghai, China, from 1896 to 1931.

Dr. *Albert Wigand*, Professor of Meteorology at the Hamburg University, and Rector during 1931-32, died at Hamburg on December 18, 1932, aged 50 years.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Apia Observatory. Annual report for 1930. Issued under the authority of the Rt. Hon. G. W. Forbes, Minister of Scientific and Industrial Research. Wellington, Govt. Printing Office, 1932 (71). 25 cm.

Bartels, J. How changes on the Sun's surface are recorded by the Earth's magnetism. Sci. Mon., New York, N. Y., v. 35, No. 6, 1932 (492-499 with 7 figs.).

Batavia. Observations made at the Royal Magnetical and Meteorological Observatory at Batavia, v. 51, 1928. Published by order of the government of the Netherlands Indies, by Prof. Dr. J. Boerema, Director. Batavia, Govt. Printing Office, 1932 (x+108 with 3 pls. of curves). 36 cm. [Contains magnetical records Batavia-Buitenzorg for 1928.]

Bombay and Alibag Observatories. Magnetic, meteorological, and seismographic observations made at the Government Observatories, Bombay and Alibag, in the year 1929, under the direction of S. K. Banerji. Calcutta, Govt. India Central Publication Branch, 1932 (iii+138 with 5 pls.). 34 cm.

Curry, P. A. Installation of the Schuster-Smith magnetometer, and the Helwan standard of horizontal intensity. Cairo, Ministry Pub. Works, Physical Dept., Helwan Obs. Bull., No. 35, 1932 (11 with 2 illus. and 1 curve). 27 cm. P.

Dahlblom, Th. Beräkning av magnetiska malmers djupgåede. Jernkontorets Ann., Stockholm, v. 15, No. 2, 1931 (95-102).

De Bilt, Kgl. Niederländisches Meteorologisches Institut. Der magnetische Charakter des Jahres 1931. Numerische magnetische Charakterisierung der Tage. Met. Zs., Braunschweig, Bd. 49, Heft 9, 1932 (358-359).

Eickelberg, E. W. Local magnetic disturbances. Washington, D. C., U. S. Coast Geod. Surv., Assoc. Field Eng., Bull. No. 5, 1932 (22 with 1 map).

Ertel, H. Zum gegenwärtigen Stand der durch magnetische Variationen induzierten Erdströme. Naturw., Berlin, Jahrg. 20, Heft 47, 1932 (860-862).

Frost, D. V. Contribution to the theory of magnetic methods of prospecting. Izv. Russ. Nauchnago Inst., Belgrade, No. 6, 1932 (87-134). Abstract: Geophys. Abstr., Washington, D. C., No. 42, 1932 (600). [Russian text.]

Gunn, R. Diurnal variation of cosmic rays and terrestrial magnetism. Phys. Rev., Menasha, Wis., v. 41, No. 5, 1932 (683).

Hamburg, Deutsche Seewarte (Dr. Burath). Weltkarte. Linien gleicher Miszweisung für das Jahr 1931. Berlin, Marineleitung, No. 1944, 1932, 2 Blätter, 85 x 87 cm. [Aequartorialmassstab 1: 28,000,000.]

Hazard, D. L. Results of observations made at the United States Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, in 1925 and 1926. Washington, D. C., Dept. Comm., U. S. Coast and Geod. Surv., Ser. No. 547, 1932 (100 with 13 figs.). 27 cm.

Heiland, C. A. Preliminary note on a new magnetometer. Physics, Menasha, Wis., v. 3, No. 1, 1932 (18-22). [A vertical magnetometer is described which is believed to fill the need for an intermediate type between the dip needle and the Schmidt balance. It does not require a tripod and levels itself. The compass for orienting remains attached to the instrument; it may also be readily compensated for temperature. It utilizes a magnetic system suspended in jewels in or near its center of gravity; the magnetic vertical intensity is balanced by the torsion of a helical spring. The magnetic system is adjusted to the normal vertical intensity in the area under survey by a suitable setting of the spring and the anomaly is roughly proportional to the angle of deflection from the horizontal.]

KEUNECKE, O. Berichtigung zu "Der tiefere Untergrund des Subherzynen Beckens und seines nordwestlichen Vorlandes auf Grund magnetischer Messungen." Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 3, Heft 1, 1932 (137-142). [For original article see Bd. 2, Heft 4, 1932 (344-373).]

KOENIGSBERGER, J. Gesteinmagnetismus und Säkularvariation. Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 6/7, 1932 (322-324).

KRAHMANN, R. Magnetic investigations as an aid to economic geology. Johannesburg, Trans. Geol. Soc. S. Africa, v. 33, 1931 (65-89). Abstract: Geophys. Abstr., Washington, D. C., No. 40, 1932 (538).

LONDON, METEOROLOGICAL OFFICE. Annual report of the Director of the Meteorological Office presented by the Meteorological Committee to the Air Council for the year ended March 31, 1932. London, H. M. Stationery Office, 1932 (54). 24 cm. [Contains brief reports on Kew, Eskdalemuir, Aberdeen, Lerwick, and Valentia observatories and on the International Polar Year 1932-1933.]

MAURITIUS, ROYAL ALFRED OBSERVATORY. Results of magnetical and meteorological observations for the months of July to October, 1931 (new series, v. 17, pts. 7-10). Port Louis, Govt. Press, 1931-1932 (110-179). 34 cm.

NEWTON, H. W. The 27-day period in terrestrial magnetic disturbances. Observatory, London, v. 55, No. 700, 1932 (256-261). [Discussion of paper by J. Bartels: "Terrestrial-magnetic activity and its relation to solar phenomena." Terr. Mag., v. 37, 1932 (1-52).]

NIPPOLDT, A. Ergebnisse der erdmagnetischen Beobachtungen in Seddin im Jahre 1931. Met. Zs., Braunschweig, Bd. 49, Heft 9, 1932 (357-358).

OTTAWA, TOPOGRAPHICAL SURVEY. Annual report of the Topographical Survey for the fiscal year ended March 31, 1931. Ottawa, F. A. Acland, 1932 (19 with illus. and maps). [From a brief account on pp. 9-10, of the magnetic declination survey-work executed by the Topographical Survey during the report year, we note that a new declination chart "Lines of equal magnetic declination and annual change in Canada for 1932" is in course of compilation.]

PETRUCCI, G. Notizie preliminari sull'esplorazione regionale magnetica della Sicilia. Universo, Firenze, Anno 13, Num. 8, 1932 (437-458 con 3 grafici, 2 carte e una cartina magnetica fuori testo). [Cenni sullo scopo della esplorazione magnetica della Sicilia, sulla organizzazione ed esecuzione delle misure, sulla costruzione delle cartine delle isodinamiche e dei profili magnetici; studio delle anomalie regionali e locali riscontrate; cenno sulla ricerca geòfisica degli idrocarburi, specialmante su quella magnetica.]

PUIG, I. El nuevo registrador magnético del Observatorio del Ebro. Ibérica, Barcelona, Año 19, Núm. 943, 1932 (152-157 con 9 figs.). [Description of high-speed recording instruments for observations during the Polar Year 1932-1933.]

REICH, H. Magnetisches Schürfen auf Rot- und Brauneisenerze. Zs. D. Geol. Ges., Berlin, Bd. 83, No. 7, 1931 (502-509).

Ergebnisse regional-magnetischer Forschung in der Eifel. Zs. D. Geol. Ges., Bd. 83, Nr. 9, 1931 (646-653).

RÖSSIGER, M., UND K. PUZICHA. Magnetische Messungen am Oberharzer Diabaszuge. Eine Studie über das magnetische Verhalten seiner Diabase und Eisenerze mit besonderer Berücksichtigung ihrer petrographischen Beschaffenheit; Beitrag zur Theorie der magnetischen Aufschlussmethode und ihre Anwendung in diesem Gebiet. Beitr. Geophysik, Leipzig, Ergänzungshefte, Bd. 3, Heft 1, 1932 (45-108).

SCHWINNER, R. Die magnetische Storung von Nieder-Kalifornien und ihre geologische Bedeutung. Centralbl. Mineral. Geol. Paläontol., B, Stuttgart, No. 6, 1932 (307-310).

SKELLETT, A. M. Probability of a magnetic storm during the solar eclipse of August 31, 1932. Science, New York, N. Y., v. 76, Aug. 19, 1932 (169).

SLAUCITAJS, L. Mesures magnétiques faites sur le territoire de la Lettonie jusqu' à 1932. Recueillies et réduites à l'époque 1930.5. Riga, Acta Univ. Latviensis, Mat. un dab. zin. fak. serija II. 4, 1932 (65-104).

Stratton, E. F., and J. W. Joyce. A magnetic study of some iron deposits. Washington, D. C., Dept. Comm., U. S. Bur. Mines, Tech. Paper 528, 1932 (32 with 20 figs.). 23 cm.

Trubiatchinski, N. Magnetometric investigation of manganese ore deposits. Leningrad, Trans. United Geol. Prosp. Surv., No. 166, 1932, 64 pp. [In Russian language.] Abstract: Geophys. Abstr., Washington, D. C., No. 40, 1932 (534-535).

Ugueto, L. Lecciones de topografía leidas en la Universidad Central de Venezuela. Segunda edición. Barcelona, Talleres Gráficos de Núñez y Cª., 1932 (448 con 130 figs.). 25 cm. [A general treatise on topography. Chapter iv is devoted to a discussion of the magnetic compass and its use in survey work, followed by considerations of terrestrial magnetism in Venezuela. On the basis of available data, an isogonic map of Venezuela has been constructed for the epoch 1930.5. Declination observations for points in Venezuela as obtained by the expedition of the Carnegie Institution of Washington in October 1931 are given in the appendix, as also tables of values of the magnetic declination at various points in the Republic together with the annual change.]

United States Coast and Geodetic Survey. Magnetic declination in North Carolina in 1930. Washington, D. C., U. S. Dept. Comm., Coast Geod. Surv., Ser. No. 537, 1932 (51 with 1 map). 23 cm. [Contains map showing lines of equal magnetic declination in North Carolina for 1930.]

B—Terrestrial and Cosmical Electricity

Anderson, C. D. Energies of cosmic-ray particles. Phys. Rev., Menasha, Wis., v. 41, No. 4, 1932 (405-421). [Cloud-chamber photographs of cosmic-ray tracks in a magnetic field up to 17,000 gauss are shown. On the assumption that the particles producing the tracks are traveling downward through the chamber rather than upward, particles of positive charge appear as well as electrons. From the specific ionization along the track it is concluded that the positives are protons, and are not nuclei of charge greater than unity. No evidence is uncovered demanding the introduction of a neutron for cosmic-ray phenomena. Eight examples of associated tracks are shown. Energies range from below 10^6 electron-volts to values in a few cases of the order of 10^9 electron volts. Energy values for 70 tracks are listed. The scattering of cosmic particles in traversing a 6.0 mm lead plate is measured.]

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Ashmore, S. E. Thunderstorm phenomena. Met. Mag., London, v. 67, No. 801, 1932 (211-212).

Baker, W. G., and A. L. Green. The influence of the Earth's magnetic field on the polarization of sky waves. Melbourne, Council Sci. Indust. Res., Bull. No. 60 (Radio Res. Board, Rep. No. 3), 1932 (34 pp.). 24 cm.

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Beals, C. S. The audibility of the aurora and its appearance at low atmospheric levels. Abstract: Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 44, No. 260, 1932 (256-257).

Benade, J. M. Secondary radiation produced by cosmic rays. Nature, London, v. 130, Nov. 5, 1932 (699).

Bennett, R. D., J. L. Dunham, E. H. Bramhall, and P. K. Allen. Intensity of cosmic-ray ionization in western North America. Phys. Rev., Menasha, Wis., v. 42, No. 3, 1932 (446-447).

Blackett, P. M. S., and G. Occhialini. Photography of penetrating corpuscular radiation. Nature, London, v. 130, Sept. 3, 1932 (363).

Broxon, J. W. Cosmic-ray ionization as a function of pressure, temperature, and dimensions of the ionization chamber. Phys. Rev., Menasha, Wis., v. 42, No. 3, 1932 (321-335).

Chapman, S. Low altitude auroræ. Nature, London, v. 130, Nov. 19, 1932 (764-765).

Clay, J., und H. P. Berlage. Variation der Ultrastrahlung mit der geographischen Breite und dem Erdmagnetismus. Naturw., Berlin, Jahrg. 20, Heft 37, 1932 (687-688).

Colwell, R. C. Atmospheric conditions and the Kennelly-Heaviside layer. Nature, London, v. 130, Oct. 22, 1932 (627-628).

Compton, A. H. Progress of cosmic-ray survey. Phys. Rev., Menasha, Wis., v. 41, No. 5, 1932 (681-682).

Compton, A. H., and J. J. Hopfield. Use of argon in the ionization method of measuring cosmic rays. Phys. Rev., Menasha, Wis., v. 41, No. 4, 1932 (539).

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Douglas, C. M. K. The thunderstorm of August 12th, 1932. Met. Mag., London, v. 67, No. 801, 1932 (210-211).

Eckersley, T. L. Polarisation of echoes from the Heaviside layer. Nature, London, v. 130, Sept. 10, 1932 (398-399).

Fujita, Y. Experimental studies on the potential method of electrical prospecting. Proc. World Eng. Cong., Tokyo, 1929, v. 37, Pt. 5, 1931 (229-242). Abstract: Geophys. Abstr., Washington, D. C., No. 42, 1932 (607-609).

Green, A. L. Height measurements of the Heaviside layer in the early morning. Melbourne, Council Sci. Indust. Res., Bull. No. 59 (Radio Res. Board, Rep. No. 2), 1932 (1-36 with 9 figs.). 24 cm.

The state of polarization of sky waves. Melbourne, Council Sci. Indust. Res., Bull. No. 59 (Radio Res. Board, Rep. No. 2), 1932 (37-80 with 22 figs.). 24 cm.

Gross, B. Zur Druckabhängigkeit der Ionisation durch Ultrastrahlung. Zs. Physik, Berlin, Bd. 78, Heft 3/4, 1932 (271-278). [Es wird unter Berücksichtigung der Druckabhängigkeit der Ionenkonstanten und unter Einbeziehung der allgemeinen räumlichen Wiedervereinigung auf Grund der Jafféschen Theorie eine Gleichung für den Verlauf des Ionisationsstromes bei hohen Drucken angegeben. Die Uebereinstimmung mit der Erfahrung erscheint befriedigend.]

Halliday, E. C. The polarity of thunderclouds. London, Proc. R. Soc., A, v. 138, No. 834, 1932 (205-229).

Harang, L., und W. Bauer. Ueber einen Nordlichtbogen in weniger als 80 km Höhe über der Erde. Beitr. Geophysik, Leipzig, Bd. 37, Heft 1, 1932 (109-115). [Parallactic film photographs were used to measure the heights of a green auroral arc with dark lower edge. Heights of 65-95 km above the ground were obtained, while a height of 80 km is the lowest reach yet known to which an aurora borealis has extended. The dark red edge could only be found in the lowest position of the arc.]

Hawke, E. L. The thunderstorm of August 12th, 1932. Met. Mag., London, v. 67, No. 800, 1932 (186-188). [To the article are appended remarks by C. K. M. Douglas on the synoptic situation associated with the thunderstorm described by Mr. Hawke.]

Hedström, H. Electrical prospecting for auriferous quartz veins and reefs. Mining Mag., London, v. 46, No. 4, 1932 (201-213).

Heiland, C. A., and W. E. Pugh. Theory and experiments concerning a new compensated magnetometer system. New York, N. Y., Amer. Inst. Min. Metall. Eng., Tech. Pub. No. 483, 1932 (42 with figs.). 23 cm.

Hess, V. F., und W. Kosmath. Luftelektrische Messungen in Innsbrucker Mittelgebirge. Beitr. Geophysik, Bd. 36, Heft 4, 1932 (439-451). [In Lans (Mittelgebirge near Innsbruck, Tyrol) numerous determinations of the electrical conductivity and the potential gradient of the atmosphere were made during July to September 1926. The results obtained show clearly the characteristics of an alpine country station. The relations between the atmospheric-electric and meteorological factors are thoroughly discussed.]

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Idrac, P. Le champ électrique de l'atmosphère aux grandes altitudes. Les travaux de l'Observatoire de Trappes. Nature, Paris, No. 2886, 1er août 1932 (123-128).

Johnson, T. H. An interpretation of cosmic-ray phenomena. Phys. Rev., Menasha, Wis., v. 41, No. 5, 1932 (545-552).

Johnson, T. H., and J. C. Street. The variation of the cosmic-ray intensity with azimuth. Phys. Rev., Menasha, Wis., v. 41, No. 5, 1932 (690).

Jones, W. N. Ball lightning. Nature, London, v. 130, Oct. 8, 1932 (545). [Brief note regarding two appearances of "ball lightning" observed by the author at Portofino, Italy, on August 31, 1932.]

Kähler, K. Ueber das Ionenspektrum der Atmosphäre. Naturw., Berlin, Jahrg. 20, Heft 43, 1932 (783-786).

Koller, L. R. Ionization of the atmosphere and its biological effects. Philadelphia, Pa., J. Frank. Inst., v. 214, No. 5, 1932 (543-568).

Kunze, P. Magnetisches Spektrum der Höhenstrahlen. Zs. Physik, Berlin, Bd. 79, Heft 3/4, 1932 (203-205).

Löhnberg, A., und W. Stern. Ein neuer Weg der karsthydrologischen Forschung durch Anwendung geoelektrischer Methoden. Zs. Geophysik, Braunschweig, Jahrg. 8, Heft 6/7, 1932 (283-305 mit 14 Abb.).

Messerschmidt, W. Ueber Schwankungsmessungen der Ultrastrahlung. Zs. Physik, Berlin, Bd. 78, Heft 9/10, 1932 (668-689).

Millington, G. Ionization charts of the upper atmosphere. London, Proc. Phys. Soc., v. 44, No. 245, 1932 (580-593). [In this paper Prof. Chapman's theory of the ionization of the upper atmosphere by solar radiation has been applied to construct a set of charts giving contour lines of equal ionic density over the surface of the earth. A simple approximate method of solving the fundamental differential equation of the theory by rapid arithmetical process is described. A brief comparison of these charts with existing empirical charts is given with a short discussion of its practical and theoretical significance.]

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Regener, E. Intensity of cosmic radiation in the high atmosphere. Nature, London, v. 130, Sept. 3, 1932 (364).

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Sachsse, H. Ueber die elektrischen Eigenschaften von Staub und Nebel. Ann. Physik, Leipzig, Bd. 14, Heft 4, 1932 (396-412).

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Schweidler, E. Die Aufrechterhaltung der elektrischen Ladung der Erde. Hamburg, Verlag von Henri Grand, 1932 (iii+68). 23 cm. Bd. [Probleme der Kosmischen Physik, Band XV.]

SEVIN, E. Sur le rayonnement cosmique. Paris, C.-R. Acad. sci., T. 195, No. 17, 1932 (698-701).

SHEPPARD, P. A. Some atmospheric electrical instruments for use on the British Polar Year Expedition, 1932-1933. London, J. Sci. Instr., v. 9, No. 8, 1932 (246-250). [The atmospheric-electric observations to be undertaken include measurements of the air-earth current, conductivity, number of "small" ions per cc, and the rate of production of "small" ions. For the conductivity and air-earth current a slightly modified form of the Wilson universal electrometer will be used and a simple attachment to the apparatus will enable the rate of production of "small" ions to be estimated. For observation of the "small" ion content Swann's modification of the Ebert ion counter has been adopted. Descriptions of these instruments are given.]

SKAPSKI, A. ST. Spectrum of cosmic radiation. Nature, London, v. 130, Sept. 24, 1932 (472-473).

STEARNS, J. C., W. P. OVERBECK, and R. D. BENNETT. Solar component of cosmic rays. Phys. Rev. Menasha, Wis., v. 42, No. 2, 1932 (317-318).

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STOPPEL, R. Die Raumladung in ihrer Beziehung zu den chemischen Komponenten der Atmosphäre. Zs. Physik, Berlin, Bd. 78, Heft 11/12, 1932 (849-853). [Es werden die tagesperiodischen Ausschläge bei kurzgeschlossenen Elektrometern in verschiedenen Gasen befindlich besprochen, und durch ein Kurvenpaar gezeigt, dass Temperaturschwankungen die Ausschläge der Nadel nicht verursachen.]

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C—Miscellaneous

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BANGKOK, ROYAL SURVEY DEPARTMENT. Report on the operations of the Royal Survey Department, Ministry of Defense, for the year 1930-31. Bangkok, Daily Mail Press, 1932 (43 with 9 index maps). 34 cm. [No magnetic observations were made during the report period.]

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